MARCH 2007

Rock&Gem

THE EARTH'S TREASURES • MINERALS AND JEWELRY

TREASURES FROM THE EARTH'S CRUST

ROCKHOUND FINDS!

TAKING THE HEAT

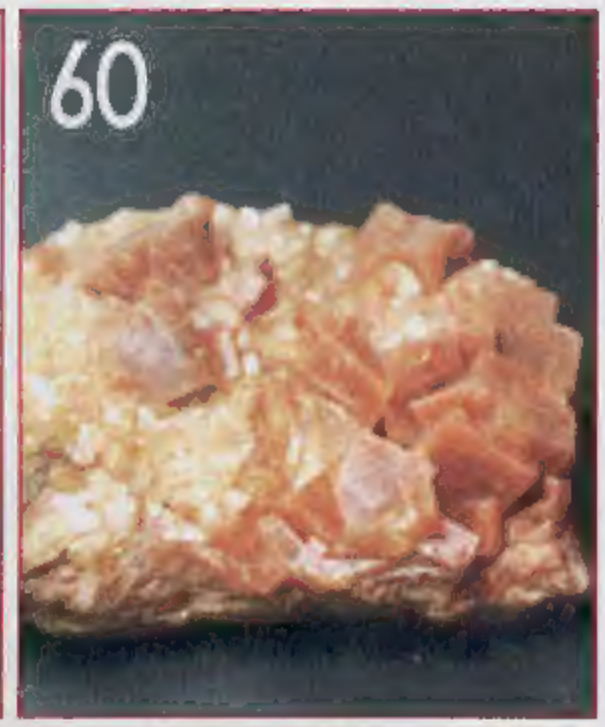
KENTUCKY POTATO GEODES

TREASURE STATE ADVENTURES

SOUTH CAROLINA'S HOT PANNING SITES

Rock&Gem

Volume 37, Number 3 March 2007



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ON THE COVER This cockscomb wulfenite on matrix comes from the Red Cloud Mine in Yuma County, Arizona. (Earl Lewis photo/Burrage Collection, Harvard)

Miller Magazines, Inc.

Rock & Gem (ISSN 0048-8453, USPS 486-280) is published monthly by Miller Magazines, Inc., 290 Maple Ct., Ste. 232, Ventura, California 93003-3517; telephone (805) 644-3824. Periodicals postage paid at Ventura, CA 93006, and additional mailing offices. Single-copy price $4.99. Subscription in U.S.A. and possessions: 1 year (12 issues) for $24.00; 2 years for $42.00; 3 years for $54.00. Add $15.00 per year postage for Canada and all other foreign countries. Submission of articles and photos by our readers is welcome, but we can accept no responsibility for loss or damage to unsolicited editorial contributions.

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Printed in U.S.A.

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POSTMASTER: Send address changes to
Rock & Gem,
P.O. Box 469113, Escondido, CA 92046-9113
or RockAndGem@pcspublink.com

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THE FRUGAL COLLECTOR

THE SILICATES

Part VII: Opal, Willemite, Nephrite and Jadeite

Story and Photos by Bob Jones

HODSON'S OF SCOTTSDALE SPECIMEN

Precious opal from Virgin Valley, Nevada, replaces a limb section.

While opal's rainbow of colors is caused by its internal physical structure, willemite can be brilliantly responsive to external energy because of its internal chemistry. Like willemite, the jades depend on metallic impurities to give them color. Jades are just one of the types of massive silcate that are hard enough to be carved and polished. This trait is one of those that make massive silicates so important in the lapidary world.

Opal, while a bit on the soft side, can be carved with care. More often, it is simply smoothed and polished to highlight the magnificent internal fire it contains. This massive, fiery gem comes in a considerable assortment of physical forms. It can be so colorless and so porous that, when immersed, it absorbs so much water that it virtually disappears in the liquid! We call this opal "hydrophane."

Taken out of water, hydrophane loses the absorbed liquid and takes on a cloudy look. Except for this entertaining property, hydrophane has little use except in uncommon cases in which it exhibits the exciting flashes of color we associate with precious opal.

Water is an integral part of opal's composition. Opal is a hydrous silicate, meaning it always contains some water; the amount ranges from a few percent in the better and more stable precious opals to the saturated condition seen in hydrophane. Most opal has a tendency to slowly lose its water unless something is done to slow the process. Simply by wearing fine opal, you can guard against moisture loss because skin oils act as a sealant. Loss of water affects opal's color, its stability, and its use as a gem material, and hence its value!

For precious opal to form at all takes several things: water as a transporting medium; volcanic ash as a source of silica; and a site that is undisturbed for a significant period of time. The key ingredient in fine opal is silica. Expelled into the air by a violent volcanic eruption, silica ash instantly cools—actually freezes—into solid silica glass fragments with no crystal form. This ash settles to the ground or a sea bottom where it slowly devitrifies, changing from glass to silica that can be dissolved. When this

happens, the volcanic silica glass becomes crystallized silica gel, which ends up in solution. This silica-rich water slowly works its way down into sediments, where it settles in any openings or seams.

Over time, the silica gel crystallizes into submicroscopic silicate quartz spherules, a form of quartz called cristobalite. In the best-case scenario, these spherules align themselves in an orderly pattern of rows. If the spherules are all nearly the same size, within certain parameters, they act as a diffracting grating when light strikes them. A diffraction grating is any orderly arrangement, like parallel lines or aligned spherules. This arrangement is able to scatter light into its individual colors. If the spherules don't align evenly or are too small, too large, or of mixed sizes, the diffraction effect is lost and there is no rainbow of color. Naturally, there is far more colorless opal than precious opal.

Some of the earliest opal ever used by people came from opal deposits in the Carpathian Mountains. The host rock is rhyolite, a high-silica volcanic rock that is often accompanied by ash discharges during eruption. The Carpathians repose largely in Hungary, but the opal deposits are actually in the neighboring Slovak and Czech republics. Carpathian opal is pretty and fiery enough to be useful in jewelry. The seams in which it forms are narrow, so the opal tends to be thin and easily cracked if not properly supported or mounted.

It is known that opal was found in Africa several thousand years ago, but no formal mining took place at that time, so the first formal opal mining seems to have started in the Carpathians around 400 B.C. These European

ELMER BOMAR SPECIMEN

This remarkable nephrite chain was carved from a single block of jade.

deposits were the major source of opal for centuries and, except for small, rather insignificant finds elsewhere, was the only important source of precious opal until Mexico, Australia, Honduras, Oregon and Virgin Valley came online, in that order.

The first reasonably good new deposit of precious opal was found in Germany about 1825. Small, colorful, rounded masses of precious opal were found there in quantity. Because of their shape, they were named "barleycorn" opal. Their impact on the opal market was minimal.

In the New World, the Aztecs and others were digging opal from yet another rhyolitic deposit at Queretaro, Mexico. This extensive occurrence is still worked today! Carpathian opal is generally gray-white with streaks and patches of color throughout. It tends to be thin, though an occasional large mass is found. Queretaro opal tends to consist of nodules that occur in gas pockets. It most often has an orange to red groundmass. Much of it shows little or no color flash, but its overall appearance, aided by random flashes of color in the groundmass, makes the opal very popular. Because of the color of the groundmass, this opal is referred to as "fire opal."

The Mexican opals occur in randomly scattered small, nodular masses in the rhyolitic rock. Their development depends on silica gel getting into small gas openings in the rock. Mining is sometimes sporadic, but the deposits in Queretaro are still being worked.

The Carpathian deposits were still the main source of opal in Europe until the early 1870s, when a first significant find of opals was made in Australia. Immediately, this find eclipsed all others. Australia provided a new type of opal occurrence. Instead of having to deal with hard volcanic rhyolite, the Australian diggers faced tough sedimentary rock.

In volcanic rock, the opal occurs in thin seams, occasionally an inch thick. The Australian opals were often found in large masses or nodules in more or less predictable horizons in the sedimentary rock. "Fossickers" would tunnel into the rock as they pursued the opal-bearing horizons.

continued on next page

Red crystals of willemite from Sterling Hill, New Jersey are often referred to as troostite.

Australian opal formed as volcanic ash settled to the floor of shallow seas that covered the land. Sea creatures died and settled into the silica mud. As the sea receeded, the land emerged and weathering began to expose the opal that had formed.

Beginning with the initial discovery in 1872, more and more Australian opal fields were discovered. Two of the more famous sources, White Cliffs and Lightning Ridge, were found in 1889 and 1900. The White Cliffs deposit produced mainly gray-white opals with good color. Lightning Ridge is far more famous for its black opal; its dark background seems to enhance the brilliance of its flashing colors. Coober Pedy also produces the gray-white opal we usually associate with Australia.

Wonderful pseudomorphs of opal-after-various sea creatures are found at White Cliffs. Snails, clamlike pelecypods, and gastropods are common in some digs. Very rare and particularly exciting are the partial remains of sea creatures called plesiosaurs, what we usually think of as ocean-going dinosaurs. A few nearly complete plesiosaur skeletons completely replaced by precious opal have been unearthed. Even fewer have survived to be put on display; many have simply been broken up and sold for their opal value, far more than a museum could pay for an intact specimen.

Another type of opal pseudomorph found at White Cliffs has been nicknamed "pineapples." These are ball-like opals with what appear to be crystal points sticking out in all directions. For a time, no one could figure out how these had formed or what had been replaced. Then it was decided they were pseudomorphs after crystallized glauberite, which is a sodium, calcium sulfate. Glauberite often forms in such a pineapple form; however, according to information in Allan Eckert's excellent book *The World of Opals* (John Wiley & Sons, 1997), the replaced mineral has finally been identified as ikaite, a hydrous calcium carbonate.

Pineapple opals are rare. The Gemological Institute of America (GIA) reported in its superb quarterly publication *Gems and Gemology* that there are probably no more than 20 such oddities still in existence, the rest having been destroyed for their gem value.

While Australia is still the world's premier source of fine opal, sources in Brazil, Honduras and elsewhere have added to the supply. In the United States, a good deposit of opal was found in Oregon's Columbian River valley in the 1890s. The site was given the name Opal Butte, though the opals occur in a much broader area. Collecting there was vigorous and fruitful. The Opal Butte deposit yields geodes that are usually filled with common opal. An occasional geode will contain bright precious opal in its interior. This and other Oregon deposits of opal are found in rhyolite or what were once rhyolitic volcanic sources, a not unusual source of geodes.

LIZZADRO MUSEUM SPECIMEN

This remarkable rare blue jadeite carving was made for Emperor Qiunlong sometime in the 18th century.

Just after 1900, a mining engineer named Marsden Nanson was riding through a desolate area of Nevada when he spotted a piece of precious opal. This triggered a search, and wonderfully colorful precious opal was discovered in that area, now known as Virgin Valley.

Dozens of claims were staked in this remarkable region, and each one produces fine opal pseudomorphs after limb sections and pinecones. The Virgin Valley opal is extremely popular as a display gem, but its reputation for cracking and crazing easily has really hampered its use as a jewelry stone. Certainly, Virgin Valley opal can be used in jewelry. It takes a fine polish and much of it is as stable as Australian opal. If its water content is high, however, it has a disappointing habit of cracking. Kept in a container of water or glycerin, it is a most attractive display gem.

Early miners in Virgin Valley soon learned of this opal's penchant for cracking. They would put their finds on the roofs of their tin shacks and let them dry out. Some would crack to pieces, but those that did not could then be sold for gem use.

There are a number of fee-digging mines in Virgin Valley. Rockhounds can enjoy the thrill of searching for, and often finding, a choice mass that flashes every color of the rainbow.

The other important opal source in America is in Clark County, Idaho, near the town of Spencer. Found by hunters in 1948, this rhyolitic opal deposit has become a wonderful source of fine opal. Next to the operating mine is a fee-dig site where collectors can break the tough volcanic rock in search of a narrow seam lined with pinkish precious opal. Some of the opal has a dark background and is really a form of black opal. This uncommon find is a worthy prize for a hard-working rockhound!

Collectors are lucky that the zinc silicate willemite comes in a variety of forms. As a fluorescent mineral, it is abundantly common from many sources, none better known than the zinc ore deposits at Franklin and Sterling Hill, New Jersey. As a mineral associated with other species, it adds to many a specimen. It occurs well crystallized and colorful and, in rare cases, as a gem. It is also an abundant ore of zinc at some sites, often found in one or more forms.

Willemite is readily associated with Franklin and Sterling Hill, New Jersey, which are the world's greatest source for the mineral and the source of dozens of the most colorful fluorescent minerals ever found. Willemite is one of the area's more common fluorescent minerals. It gives a brilliant green response under short-wave ultraviolet light. Crystals and solid masses can be naturally red or light green, and less often yellow-green. It can even be black, given enough impurities.

The deposits produce willemite in glassy to opaque crystals that are often rounded on the edges due to enclosing calcite or another mineral. It is also very often massive, as part of chunks of ore made up of red zincite, black franklinite, and white calcite. The willemite can be gray to white to black, sometimes occurring as thick green to white bands in the ore or as textbook, sharp, red or green crystals. Banded willemite is particularly popular with fluorescent mineral collectors, as they are rare and very responsive under short-wave ultraviolet.

Willemite constituted one of the major ores at Franklin-Sterling Hill, along with zincite, a zinc oxide, and franklinite, an iron, zinc mineral.

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Willemite is also found in the famous specimen locality at Tsumeb, Namibia. If you put a Tsumeb specimen next to a New Jersey specimen, you would think you are looking at two distinctly different species! On the other hand, if you put a Tsumeb willemite next to one from the Mammoth-St. Anthony Mine in Tiger, Arizona, you'd see some remarkable similarities, as well as minor differences.

The Tsumeb willemite tends to be gray to green crystalline masses showing botryoidal form. It is not an abundant mineral there or at Tiger, so it does not constitute a significant zinc ore. Neither Tsumeb nor Tiger willemite responds to ultraviolet excitation.

Lesser-known sources of nice willemite include Balmat, New York; the Cerro Gordo mines of Inyo County, California; South Australia; and Mont St. Hilaire in Quebec, Canada. A large number of almost nameless silver-lead-zinc mines and prospects in the Arizona desert also produce the mineral. For example, the Red Cloud Mine, famous for its amazing red wulfenite blades, is a good source of massive, fluorescent willemite, associated with calcite that fluoresces red, and blue fluorescent fluorite.

North of Wickenburg, Arizona, there are a number of small mines whose dumps still yield a calcite, willemite, fluorite suite of fluorescent minerals. The best known is the Purple Passion Mine, a working specimen mine that also produces wulfenite. Local clubs are also invited to collect there for a fee.

Some 30 or so years ago, I collected at a prospect near Red Rock, Arizona, that produced a bright red-green combination of willemite/calcite fluorescent material very much like the more famous Franklin-Sterling Hill material. The Red Rock deposit was almost always credited to the town of Casa Grande, about 30 miles away. I suspect this was done to discourage visitors. The deposit never produced crystals, only small green-fluorescing spots of willemite in massive calcite that fluoresced red.

What made collecting easy at this site was the 3-foot-wide calcite vein turned brown by weathering. It stretched several hundred feet across the surface of the desert floor. Because the willemite was not profuse, Red Rock specimens usually look like poor-grade Franklin material.

The premier willemites are the crystallized specimens from Franklin and Sterling Hill. Of the two, Franklin seems to have been the more important source of crystals. Franklin crystals can

LIZADRO MUSEUM SPECIMEN

Jadeite boulders often have a yellow rind which is incorporated into the final carving.

be transparent, small, prismatic and colorless; gemmy, yellow to green crystals; or much bigger, translucent to opaque, reddish-brown crystals embedded in white calcite with contrasting black franklinite, red zincite, and sometimes brick-red rhodonite. The gemmy crystals were always very rare, while the opaque to translucent crystals were very common and constituted one of the major ores. However, the vast majority of this green fluorescing mineral at both Franklin and Sterling Hill is massive. The material is often opaque, but sometimes occurs as glassy, grainlike masses locked in place within the ore.

The ore is often a mix of red, white, cream and black, and can be cut and polished. It was common practice when the mines were working for a few local lapidaries to obtain solid pieces of ore and create lovely cabochons in a variety of shapes. Good, solid pieces could also be shaped into spheres. The random red, white and black shades of the ore always made attractive stones. When you put a polished cabochon of Franklin-Sterling Hill ore under the ultraviolet lamp, the vibrant color response was intense.

One fun thing to do with a polished sphere of Franklin-Sterling Hill ore is to see calcite's brief phosphorescence. If you put a sphere containing the calcite in front of a UV lamp and spin the sphere, the side away from the UV source will continue to glow red.

Willemite almost never occurs as chemically pure zinc silicate. Manganese and iron can both substitute for zinc atoms and often do. In fact, willemite's lovely fluorescent response, which ranges from yellow to intense lime green, is due to traces of manganese. Iron can limit or even extinguish willemite's green response. When iron is a significant fraction of the willemite, its natural color is brick red. The now-discredited name "troostite" was once used for red willemite. You'll still hear it frequently in conversations with collectors of Franklin and Sterling Hill minerals and you'll see "troostite" on display at any Franklin, New Jersey show!

The finest collection of willemite on public display can be seen at the Sterling Hill Mining Museum in Ogdensburg, New Jersey. The museum is divided into several sections, including the Thomas Warren Fluorescent Museum, home to an amazing assortment of Franklin-Sterling Hill fluorescent minerals. There are cabochons, spheres, slabs, and natural crystallized species, all of them fluorescent.

There is another type of Fraklin-Sterling Hill willemite that is usually incorrectly referred to as secondary willemite. It has an amazing green phosphorescence that can be so bright you can read a paper in its green glow. This material can continue to phosphoresce for hours after exposure to short-wave ultraviolet.

Those who favor the fluorescent minerals can take a guided underground tour at the Sterling Hill Mine and Museum. You'll enter a tunnel that has a number of large, strong, ultraviolet lamps in place. With ordinary lights turned off and the ultraviolet lights on, an entire wall of fluorescent willemite and calcite lights up like an ethereal rainbow.

The willemite from Tsumeb is mostly found in small, radiating bundles of white to gray needles that were not recognized as willemite at first. Another common form is small aggregate balls of different colors: sometimes blue, sometimes gray, sometimes yellow. It also formed pseudomorphs after mimetite and has the familiar grapelike habit. The most attractive willemite occurs in lustrous blue-green balls that are most often about ¼ inch in diameter. The Tsumeb willemite does not respond under ultraviolet light because it contains no manganese. Its primary popularity seems to be as a mineral associated with showier species.

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The Mammoth-St. Anthony Mine willemite was generally a blue to blue-gray color. It formed as small, botryoidal coatings not unlike those from Tsumeb. What distinguished the Tiger willemite were the bright, orange-red wulfenites and snow-white V-twinned cerussites that have formed on the willemite. Though these mines have been closed for decades, there are still plenty of fine Tiger minerals, including willemite, available.

Mont St.-Hilaire, Quebec, is one of Canada's most important species deposits. Its willemite forms unusual blue prisms that are as much as an inch long. These are uncommon and are eagerly sought by collectors.

Boulder opal has plenty of color but is usually quite thin as it forms in seams of ironstone.

Two gem silicates that are exceedingly popular, particularly in the orient, are jadeite and nephrite. The former is a mineral, the latter a mixture of two minerals. Any important museum—the Los Angeles County Museum of Natural History, the American Museum of Natural History, the Lizzadro Museum of Lapidary Art, and a dozen more—display a wide range of artwork done with these gems.

Most mineral collectors don't have either jadeite or nephrite in their collections unless they are also lovers of lapidary art. When polished, these silicates take on a soft glow that highlights their color. Their compact structure makes them tough to work on, but dependable, as they seldom fracture or cleave.

The premier source of jadeite is Myanmar (formerly Burma), specifically Tawmaw, Myitkyina, Mogaung, Kachin State, North Myanmar. The gem rough is found in a series of metamorphosed dikes and outcrops that run over two miles long. The deposit is due to high-pressure metamorphism, typical of deposits where the mineral is found. Myanmar certainly produces the world's best jadeite. The superb Chinese jadeite carvings are produced from material that originated in this deposit. It still produces the better jadeite after centuries of mining.

Though jadeite is a mineral, it varies greatly in composition. It is a sodium, aluminum silicate, which suggests that at least some of the rocks involved in the metamorphic process have to be high in aluminum. Jadeite also contains chromium or iron atoms acting as chromophores. These metal impurities affect the color, which can range from mutton fat through various shades of green and lavender.

In 1932, nice jadeite was found in current-day Kazakhstan. A considerably larger deposit was found later in the North Polar Urals of Russia. In the United States, jadeite has been found in California's Coast Ranges. Clear Creek, in San Benito County, produces small amounts of jadeite.

The Aztecs and Olmecs used jadeite in their art and religious symbols. Though there were plenty of artifacts, the jadeite deposit remained lost until a few years ago, when a heavy storm tore away a hillside in the Montague River Valley of Guatemala, revealing huge boulders and outcrops of jadeite that match the archeological votives.

Nephrite is a far more common form of jade. All the Chinese jade carvings going back 4,000 years are done with nephrite from the Kunlun Shan Mountains in far-eastern China. The nephrite was probably first found as boulders weathered out of this metamorphic deposit. Eventually, the gem deposit was found and a vigorous trade with a regular transportation route developed.

The composition of nephrite varies considerably, but it is basically a fibrous intergrowth of two similar minerals, actinolite and tremolite. It forms during the metamorphic action of ultramafic rocks, which are high in manganese and iron. It is also found in metamorphic skarns, the contact between limestone and mafic rock.

Nephrite has been found in quantity in far more places than jadeite has. Best known in recent years are the discoveries of huge, green nephrite boulders in British Columbia and the Yukon region of western Canada. Prospectors found the source of this nephrite, and huge operations were started to cut up the boulders and begin mining for more. The nephrite is mainly exported to—where else?—China.

Not all nephrite is green. Some green nephrite is due to an iron chromophore, but a slightly different form of iron can turn it yellow. Graphite inclusions produce black nephrite, and iron hydroxides can cause lovely brown-red nephrite. The brightest green—and the most valued—nephrite is colored by either chromium or nickel.

The Maori of New Zealand were able to mine nephrite jade right in their backyard. The deposits are found in a talc-serpentine rock in the Griffin Mountains. The glaciers that are fairly common in New Zealand may have brought the first nephrite rocks out of the mountains. The grinding action of glaciers flattened some of the nephrite, and these rocks were easily transformed into weapons and tools.

The largest nephrite deposit in Europe occurs in the Ligurian Apennines and may have been worked by early lake dwellers in northern Italy and Switzerland. It is eclipsed now by larger deposits in Canada, China and Myanmar.

Siberia is rich in nephrite, but these remote deposits are not worked extensively due to the lack of easy transport. The deposits were first found in 1851 as surface boulders in the Eastern Sayan Range. When I was in Russia, I was told the major deposit is a 3-foot-thick vein that runs across the face of a mountain. The famous artisan Peter Carl Fabergé used a lot of Siberian nephrite in his now-famous objets d'art.

When I visited the Gems Museum in Moscow, I was impressed by the large, cut pieces of nephrite on display. The Gems Museum is charged with promoting the stone industry in Russia, so a great variety of major stones like nephrite, charoite, rhodonite and malachite are on exhibit.

Massive carving and lapidary materials such as jadeite and nephrite are generally not eagerly sought by "pure" mineral collectors, who will only collect crystallized specimens. However, these two lovely minerals, when elegantly carved, are exceedingly beautiful and well worth adding to any collection.

The seven articles in this series represent a "writer's choice" of silicate minerals; certainly, there are far more silicate minerals than those I have described. Those I have covered are among the more commonly sought collector minerals.

Shop Talk

William A. Kappele

Wire-Wrapped Jewelry

I think I'm right in assuming that when most of us begin the lapidary hobby by cutting cabochons, we don't think beyond the fun and wonder of taking a sometimes grungy-looking rock and turning it into a thing of beauty. This works just fine for a while, but before long, we begin to notice that cabs are piling up all over the place. We have to do something with them, so we start with Riker mounts. Good! Having all our treasures behind glass in a nice frame is great. But the walls are getting a little crowded and maybe the décor could stand something besides cabs. The answer is to start making jewelry.

Again, most of us take this step by picking up some ready-made cab mounts at our favorite rock shop, lapidary supply, or rock and gem show. Unfortunately, the availability of really nice mounts is pretty limited, and some of them look awfully cheap (and I don't mean inexpensive). If we are to get what we want, we will obviously have to make them ourselves.

Traditional silversmithing techniques will produce what we want, as will lost wax casting. These both require a fair amount of expensive equipment, though. A really good alternative for those who don't want to end up in the poorhouse is wire wrapping. The materials are inexpensive, the tools are minimal, and the technique can be learned in a hurry.

I think the best way to learn is by finding a way to get hands-on experience in a class or with someone who can devote some time to getting a beginner started. These aren't the only ways, by any means. If you have access to the Internet, you can find a lot of sites with step-by-step photos to get the idea across. One such site, www.rockhounds.com/rockgem/articles/wirewrap.html, features an article on making a wire-wrap pendant from *The Wire Artist Jeweller*, a well-known Canadian semi-monthly magazine (www.wag.on.ca). The instructions are clear and the photos are excellent.

There are, of course, many wire wrapping books on the market. I recommend that you look them over carefully to be sure you understand the illustrations. Photos are generally easier to follow than drawings. Don't worry too much about the designs in the books; once you master the basic techniques, you will be in charge of the design and the possibilities will be limited only by your imagination.

The wire most often used in wire wrapping is 22-gauge gold-filled or silver with a square cross section. The higher the number of the wire gauge, the finer the wire is. If you want a medium-thickness wire, 22 gauge is about right. A 20-gauge wire is great for retaining its shape in case Aunt Freda wants to back the Chevy over it.

A good basic set of tools will include a set of jeweler's pliers, including diagonal and end cutters, round-nose pliers for scrolling and bending loops, and flat-nose pliers for bending, twisting and crimping. You need not spend a fortune on pliers. In fact, a very inexpensive set will get you started and will probably last you for years. One thing to avoid, though, is flat-nose pliers with teeth in the jaws. You don't want to scratch your work before it is even finished. Leave that to Aunt Freda. A set of small Swiss pattern files and a pin vise will complete your tool set. It is also a good idea to pick up a jeweler's polishing cloth to put the final touch on your masterpiece.

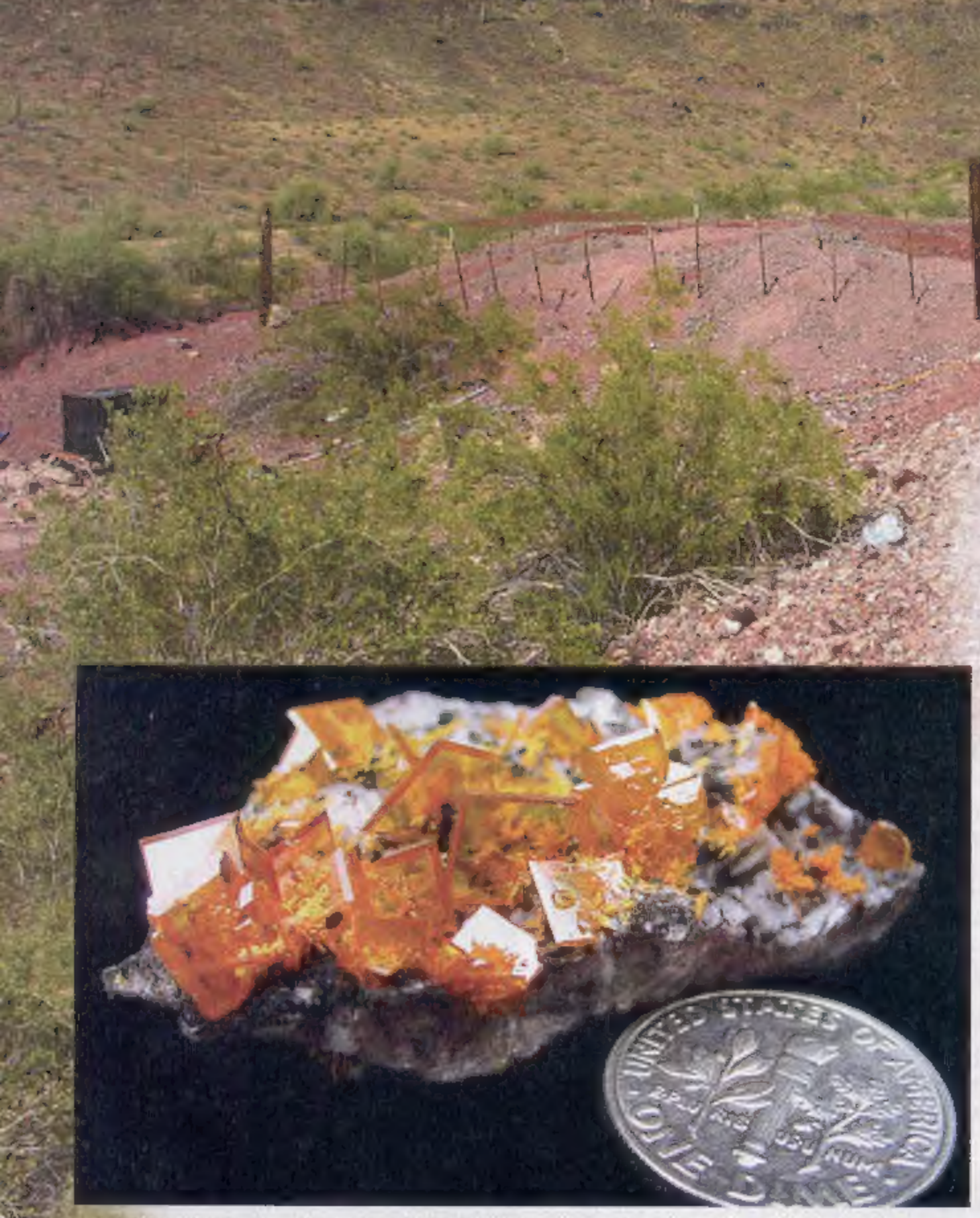
Happy wrapping!

Please feel free to contact me if you have a suggestion or comment about this or any of my Shop Talk columns. My e-mail is quappelle@cox.net, or write to me at 25231 Pericia Dr., Mission Viejo, CA 92691.

ROCKHOUNDING THE ROWLEY MINE

Wulfenite and Mimetite in Arizona's Maricopa County

Story and Photos by Mike Streeter



Mimetite is a secondary mineral found in the oxidized zones of arsenic and lead deposits.

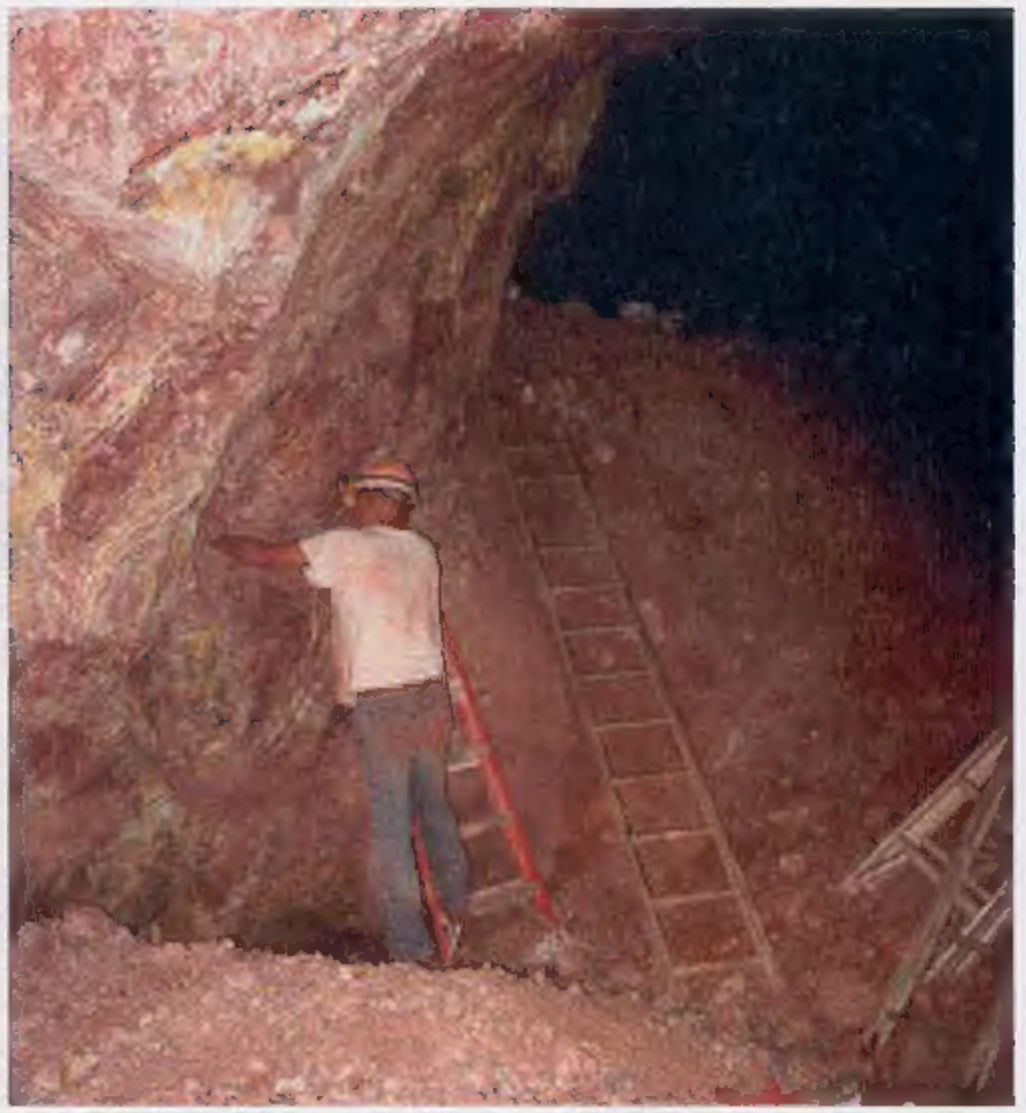
Opal, get back here," I bellowed as the dog tore off in hot pursuit of a fleeing lizard that had been innocently basking in the southern Arizona sun. She had somehow managed to spot it only seconds after my wife, Chrissy, let her out of the back of our truck. Eons-old natural selection and animal instinct were continuing to play out as dog chased reptile.

There was little doubt that the Sonoran Desert fringe-toed lizard had survived countless other life-and-death chases by hungry predators looking for a quick meal; seeming to defy gravity, the lizard shot up a gray concrete block shed and into a narrow, dark opening beneath a curled up metal roof. Opal tried to follow, but gravity won out this time and she slid back down to the ground.

If she could talk, Opal would, without looking you directly in the eye, tell you that she only chases lizards for sport and that she doesn't even like their taste. All I can say is that she is fortunate to always have a dog food bowl with her name on it because, so far on our trip, the running score was lizards 231, Opal 0. It was also a good thing that Chrissy's and my "score" was far better than Opal's when it came to our Rowley Mine hunting that day.

Our plan for Easter Sunday 2006 was ambitious. We broke camp in Wickenburg,

Fine mineral-laden pockets may be found by following the right veins in the Rowley Mine walls.



Mimetite and wulfenite specimens may be recovered from collapsed pockets in the Rowley Mine's barite vein.

Arizona, where we had spent three days of successful rockhounding in the area. Hooking up our folding travel trailer, we drove 90 miles south to Augie's Quail Trail RV Park in Gila Bend. The Arizona winter camping season was all but over and the park owner had planned to shut off the water that day, but he very graciously left it on just for us. Previous experience has taught us that it would likely be dark when we returned to Augie's tired and dirty, so we set up camp before hitting the road for the Rowley Mine, where I had previously arranged to meet Bill Jaeger. Bill, Jim Ricker, and Ed Davis are currently leasing the property and working the subsurface mine for mineral specimens.

We arrived at the Rowley around 10:30 a.m. We knew that someone must be there because of the parked vehicles, but it was eerily quiet. The mine's location on the western flank of the Painted Rock Mountains in Maricopa County afforded a nice view of the surprisingly green Dendora Valley to the west. The rustic cement block shack appeared to be empty of life, save for the aforementioned lizard. We made our way over to the entrance to the mine, which was well fortified with heavy-gauge steel plates and mesh. It was easy to see that it would be just about impossible for any uninvited person to access the mine while the owners were away.

I used a two-way radio that was hung on a post to get someone's attention. Within a few minutes, Jim answered my call and came up out of the mine to greet us. He said Bill would have come out, too, but multiple knee surgeries cause him to limit the number of trips he makes up the many ladder rungs to the surface.

Jim showed us around the area and showed Chrissy the best places to to collect in the spoil piles. Chrissy, who is a bit claustrophobic, opted to stay above ground. Opal was game to go down, but she couldn't because Jim's extra hardhat didn't fit her. After a short but thorough mine safety speech, I gathered up my gear and prepared for the descent.

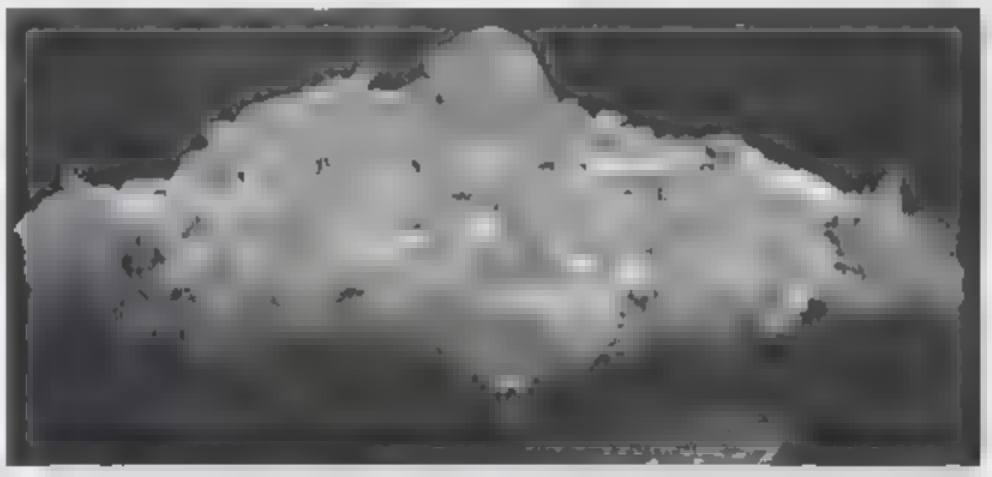
One after another, in fine MSHA fashion, Jim and I carefully climbed down a series of vertical and inclined ladders to well over 100 feet below grade. As I stepped off the last ladder rung, the relatively narrow shaft leveled off and opened up into a much larger room with drifts and tunnels heading off in various directions. This particular room was obviously "operation central" and contained metal shelving units, boxes, tools, and other rockhounding gear and equipment.

Crystallization of burnt orange wulfenite appears to predate that of the bright yellow mimetite at the Rowley Mine.

continued on next page

Rockhounding the Rowley Mine *from page 21*

Jim gave a shout and Bill climbed out of a steeply inclined tunnel, where he had been working, to greet me. Like Jim's, Bill's face was covered in a layer of reddish-gray dirt that made his eyes and teeth look bigger and whiter than they really were. To Bill, there was no time like the present to take a break, so the three of us sat down in the main room and exchanged bios and other pleasantries.



Wulfenite is a secondary mineral produced in the oxidized zones of lead and molybdenum deposits

I learned that both men were in the process of lengthening a deep tunnel in order to prospect for other mineralized zones. They took turns crawling down into a narrow passage where they used a hammer drill and other tools to extend the tunnel. They generously allowed me to collect in what they call their "production area," from which many fine specimens of wulfenite (or "wulfies," as Bill says) and mimetite had been collected in the past. They had recovered some of the finest wulfies ever to come out of North America from the Jaegermeister and Crybaby pockets.

Crybaby? According to the guys, there had been a long dry spell during which nothing much was found and a lot of whining took place just before they hit a huge wulfenite pocket that contained crystals up to 2 inches. They named it the Crybaby pocket as a mock tribute to their infantile behavior before the big strike. The Jaegermeister pocket's name is self-explanatory, or at least the "Jaeger" part is.

When Bill and Jim found out that I was a geologist, they asked me what geologic information I knew about the Rowley and surrounding area. Neither were slouches when it came to their own geologic knowledge, but I offered up what I had garnered from the Internet.

The Rowley, named after Jack Rowley Fredrick, was discovered in 1900 and was mined for lead, gold, silver, molybdenum, barite and fluorspar from 1909 to 1923. Workings included the main inclined shaft at 265 feet deep, an inclined shaft at 125 feet deep, and a vertical shaft at 163 feet deep. There are also approximately 1,850 feet of drifts. The 125 level followed the main quartz and barite veins for 370 feet (Arizona Dept. of Mineral Resources, Arizona Barite Mine File, Rowley files, MRDS files #10008298, 10234802, 10137899). Since its closing in 1923, the mine has become best known to rockhounds and collectors for its world-class burnt-orange wulfenite and striking yellow mimetite specimens. The long list of other collectable minerals includes vanadinite, galena, azurite, malachite, barite and pyrite (W.E. Wilson and D.K. Miller, "Minerals of the Rowley Mine," *Mineralogical Record*, 1974, Vol. 5, pp. 10-30).

Rowley Mine mineralization is a result of faulting, fracturing, and subsequent high-temperature hydrothermal activity associated with Tertiary volcanics. Tertiary andesite flows underlie the Rowley. A N30°-37°W striking normal fault that dips 37°E. to 56°E. cuts these rocks. Mineralization is referred to as the Rowley Vein and consists primarily of a barite vein on the headwall and a quartz vein on the footwall. A NE-SW shear zone may also be present as a fault with andesite to the NW and Precambrian phyllite to the SE.

The quartz vein is a fairly uniform 5 feet wide. A few widely spaced, tight fractures cut it and extend a few feet into the andesite. The barite vein ranges from 15 to 30 feet in thickness. Fault gouge separates the barite from a 3- to 4-foot-wide zone of fractures and slightly brecciated andesite. Barite usually occurs as masses of stringers parallel to the strike of the vein. Molybdenum minerals, including wulfenite and molybdenite, are present in both the quartz and barite veins near their common contact. Stringers and pockets containing wulfenite, mimetite and other minerals are present in the barite vein. Some of the stringers cut through malachite and chrysocolla bands and have silicified the minerals (J.W. Anthony, et al., *Mineralogy of Arizona*, 3rd ed., 1995, www.mindat.org).

After their cigarette butts were stepped out, Bill and Jim gave me the nickel tour of the underground workings, pointing out the areas in which some of their biggest strikes had occurred and where my best chances for success might be. I was told that knowing where not to dig underground in the Rowley is equally important as knowing where to dig, and I was shown the various unsafe spots. While Jim returned to the depths to continue his dirty work, Bill gave me some more specific advice before sitting down with a screwdriver to continue working a vein that he had located earlier.

There was a whole lot of color showing on the walls, but recovering any decent crystals was a real chore, as the actual pockets were well hidden behind the hard rock. After a short while, I managed to find a small exposed pocket that contained a few excellent bright-orange wulfies. The pocket was in a somewhat awkward location in terms of recovery, but I was eager to recover crystals and I went for it anyway. After about 45 minutes of banging away with my 6-pound sawed-off sledge and pointed chisel, it seemed that I was no closer to recovering the crystals than I had been when I started. The brecciated and massive barite rock wouldn't crack despite my continued forceful efforts. I started to feel like a sculptor, as all I had accomplished thus far was to carve a wide groove around the pocket's perimeter so that it became contained in rock that stood out a few inches from the wall.

At about the one-hour mark, I placed the point of my chisel on the upper side of the pocket-containing rock and let loose with a few mighty blows. Some of the above rock finally split and a softball-size hunk fell to the floor. I instantly lost all interest in the small pocket that I had been futilely trying to recover. Behind where the fallen hunk of rock had been was a relatively large crystal-lined pocket that ran up and into the wall at about 30 degrees from vertical.

"Momma!" I said. Somehow I had lucked into finding a *real* pocket that was full of beautiful wulfies and mimetites!

This particular pocket consisted of what appeared to be a collapsed fault breccia with relatively flat rock fragments that were half-loose and stacked at odd angles to each other. Perfectly formed and brightly colored wulfenite and mimetite crystals covered nearly all surfaces of the rocks and sides of the pocket.

It took the next couple hours to fully exploit the pocket. First, I had to widen its opening so that I could more easily reach in and pull out rock fragments that contained the goodies. Recovering mineral specimens without damaging them took great care and patience. It was almost like the old game of pick-up sticks that I used to play as a kid, except that I had to work above my head and pull out loose, mineral-laden rocks without having others fall out. One wrong move would have caused all the rocks in the pocket to come tumbling out at once, and this avalanche would have surely destroyed most of the delicate crystals.

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Rowley Mine *from page 22*

As if this wasn't challenging enough, the only way to reach and work the overhead pocket was to bend over backward and rest my upper back on a rounded shelf of rock. I found out in a hurry that it gets really hard to breathe in this arched-back position. As Bill said when he walked by and heard me complain of my awkward position and shortness of breath: "Gives you an idea what it would be like to be crucified."

I cleaned out the pocket as best I could. After finding a couple flats with excellent specimens, I decided to leave the rest until after lunch. I realized that I was too fatigued to be able to continue with the care that was required to not damage what remained. Besides, I was pretty darned satisfied with what I had recovered thus far. Before making our way back up to the surface to eat and breathe, Bill, Jim and I sat around and exchanged stories, most of them true and some with great embellishment.

We spent about an hour on the surface with Chrissy and Opal, eating lunch and swapping even more stories, before we went back down into the big hole in the ground. While Bill and Jim went back to their respective mining operations, I returned to my pocket to see what remaining crystals could be recovered. I managed to pull out a few small specimens before we called it a day. It was ironic, although understandable, that the small pocket that I had originally attempted to recover was still there on the wall when I left.

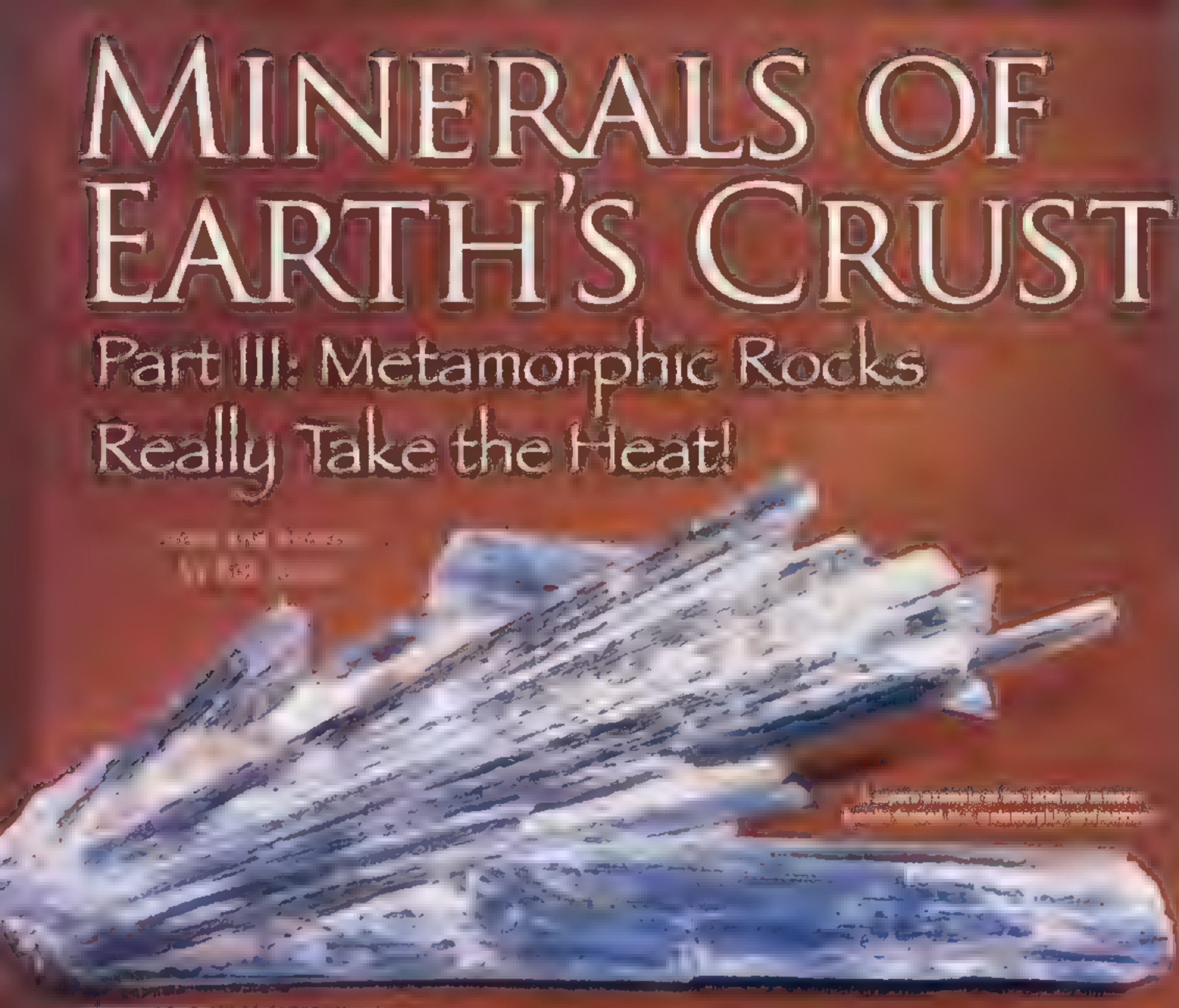
We all sat outside the shack for a while to talk. Jim gave Chrissy a lesson in crystal wrapping that proved very useful to our wulfies and mimics (my new name for mimetites). All the specimens made it home to North Carolina without a bit of damage. Just after sunset, Chrissy, Opal and I bade our farewells, packed up, and headed back to Casa Bend.

We can't thank Bill or Jim enough for allowing us to be a part of their world for the day. Both men are bursting with humor and goodwill and are well on their way to achieving legendary rockhound status.

It is important to note that the Rowley Mine is not open to general rockhounding and you must obtain permission from Jim, Bill or Ed before accessing the property. Please bear in mind that there is no guarantee that they will allow you to enter the underground workings on any given day because their commercial mining activities may preclude safe access. Contact Bill at (602) 547-2234 or Ed at (602) 569-2474. More information can be found at the Web sites www.thearizonaexperience.com and www.fluorescents.com/mr2001.htm. Go to the field trip reports page on www.mcrocks.com for more pictures of the mine and its minerals.

Minerals of Earth's Crust

Part III: Metamorphic Rocks Really Take the Heat!



Editor's Note: Look for Part I of this story in November 2006 and Part II in the February 2007 issue of *Rock & Gem*.

Any time crustal rock, whether it is igneous, sedimentary or metamorphic, is subjected to enough heat and pressure, its chemistry and structure change. The interesting result may be new minerals, a rock with greater hardness, or a rock with unusual and very beautiful swirling, banded patterns that were not there before. These properties make some metamorphic rocks very attractive and marketable. One of the new and very attractive uses for such rock is as kitchen countertops.

The thing to remember about metamorphic rock is that changes to crustal rock had to take place deep enough in the crust that weathering did not penetrate and play a role in any changes. Any metamorphic action that brings about changes in rock requires enough heat, pressure, or chemical invasion to cause profound recrystallization. Amazingly, the rock remains solid during these stresses and changes, even though all sorts of mineral molecules are able to move about, attach, separate, and re-attach as if the host rock were fluid. The word "plastic" best describes the condition of most rock being subjected to metamorphism.

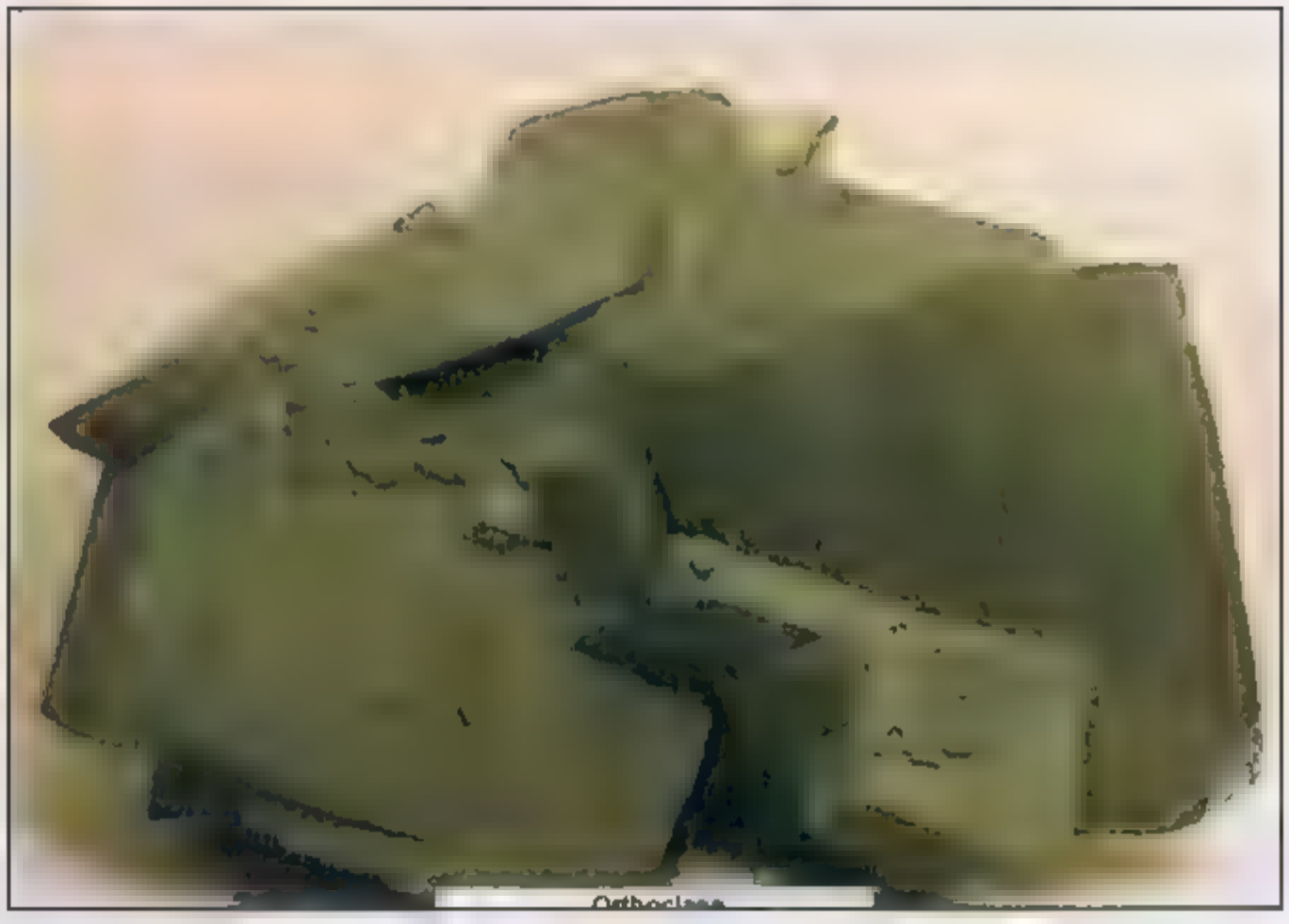
You might wonder why minerals that are already formed in a rock are able to change to something else during metamorphism. After all, these minerals are more or less stable. If they weren't, they would change until they reached stability.

When stable minerals are subjected to heat, pressure, or chemical invasion, they come under stress and their crystals become less stable. They have no choice but to strive to reach stability, even if it means changing crystal form or becoming a different mineral! During metamorphism, the chemistry of a mineral may change or the mineral may simply change crystal form to accommodate the added heat energy or pressure. A couple of examples of quartz at this condition.

In studying the rocks around Meteor Crater in Arizona, scientists have found that two new varieties of quartz were formed by the intense heat and pressure created when the meteor collided with Earth's surface rocks! The rocks of the meteor strike area, known as the Mogollon Plateau, are largely sedimentary sandstone, and sandstone is primarily granular quartz. When the meteorite hit, the quartz in that sandstone was forever changed.

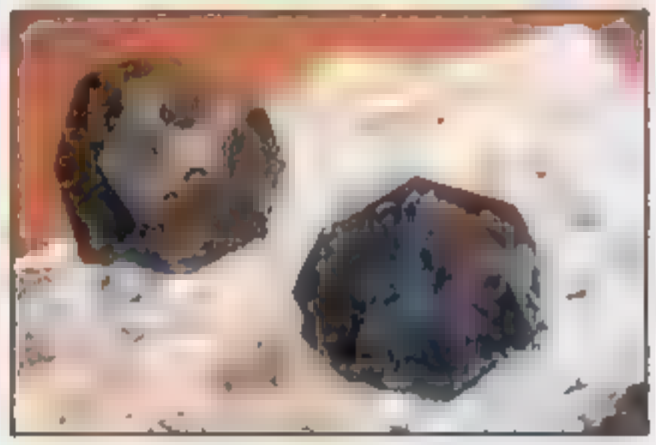
Normally, quartz is a hexagonal silicon dioxide mineral. The quartz at Meteor Crater changed crystal form to create two new silicon dioxide species. One developed a monoclinic form. We

A 3-foot slab of charolite is on display at the Mining Institute in St Petersburg, Russia



Green chlorite completely coats an adularia crystal specimen from Switzerland

Pyrite is another mineral found commonly in metamorphosed schist.



These textbook garnets are locked in the schist in which they formed

call it coesite The other, stishovite, developed in a tetrahedral crystal form. These are the obvious metamorphic changes resulting from excess heat and pressure This extreme case of change has helped scientists identify other less obvious meteor impact craters on Earth

Deep in the crust of the Earth, metamorphic forces are applied over vast periods of time, and time allows dramatic changes to take place If the forces are not too intense, slight changes occur Intense forces, like a meteor impact, bring about profound changes

Scientists group metamorphic rock into two basic types, regional and contact Contact metamorphic rock develops in a relatively restricted circumstance Meteor Crater is a good example of a contact metamorphic site When a hot mass comes into contact with existing host rock, the heat and pressure have a profound effect on the nearby host rock Where magma may move toward Earth's surface, the host or country rock, assuming it does not melt, is changed The change may result in a plastic state of the rock The heat from the intruder energizes once stable minerals in the host rock so that they destabilize and change to a different mineral with a different set of physical and maybe chemical properties They change to more stable minerals that differ from the originals

In some cases, fluids may be injected into the host rock, and this can change the rock's chemical composition. A prime example of this is a copper porphyry ore body. The host rock is normally too low in metallic content to be useful as an ore, but hot fluids rich in copper can diffuse throughout the host rock, depositing enough copper in the rock to raise the metal content and turn the porphyry into pay ore. Bisbee, Arizona, Bingham Canyon, Utah, and a host of other deposits in the American Southwest are such copper porphyries. They are considered metamorphic because of the changes wrought by the chemical invasion that occurred On their own, copper porphyry deposits offer little to the collector, but when weathering gets involved, it brings about marvelous changes!

A more exciting example of a contact metamorphic deposit occurs when heat and pressure attack a limestone rock formation These are often called skarns, a special type of metamorphic circumstance that yields some very interesting minerals. The impurities in the limestone get all excited from the heat and pressure and begin moving about, forming new minerals. Such species as vesuvianite, epidote, and one of several forms of garnet are often found in skarns associated with limestone

A good example of such a skarn deposit is on Green Monster Mountain, Prince of Wales Island, Alaska The change wrought here created several fine collector minerals, primarily excellent epidotes. Associated with them are choice quartz crystals, many showing Japan Law twinning Garnets are also found there, as are minor amounts of other species All have resulted from contact metamorphic action

An interesting circumstance about metamorphic rock over a broad area is that the results of the forces of change vary within the entire body of rock The rock closest to the source of heat, pressure, or invading chemicals will be affected more intensely than rock hundreds or thousands of feet away

The other, much more extensive type of metamorphism is referred to as regional metamorphism a term that really needs no explanation. This develops when exceedingly large landmasses move and exert huge and inexorable pressures over vast distances The intense pressure creates heat in a second large rock body Over long periods of time, this stress creates vast changes over huge areas of rock Regional metamorphism may involve thousands of square miles of rock Obviously, changes will vary according to distance from the source of stresses.

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Minerals of Earth's Crust *from page 29*

One of the more important types of regional metamorphism happens when two crustal plates grind against each other. Though such huge masses move only an inch a year, the stress is enough to create mountain ranges!

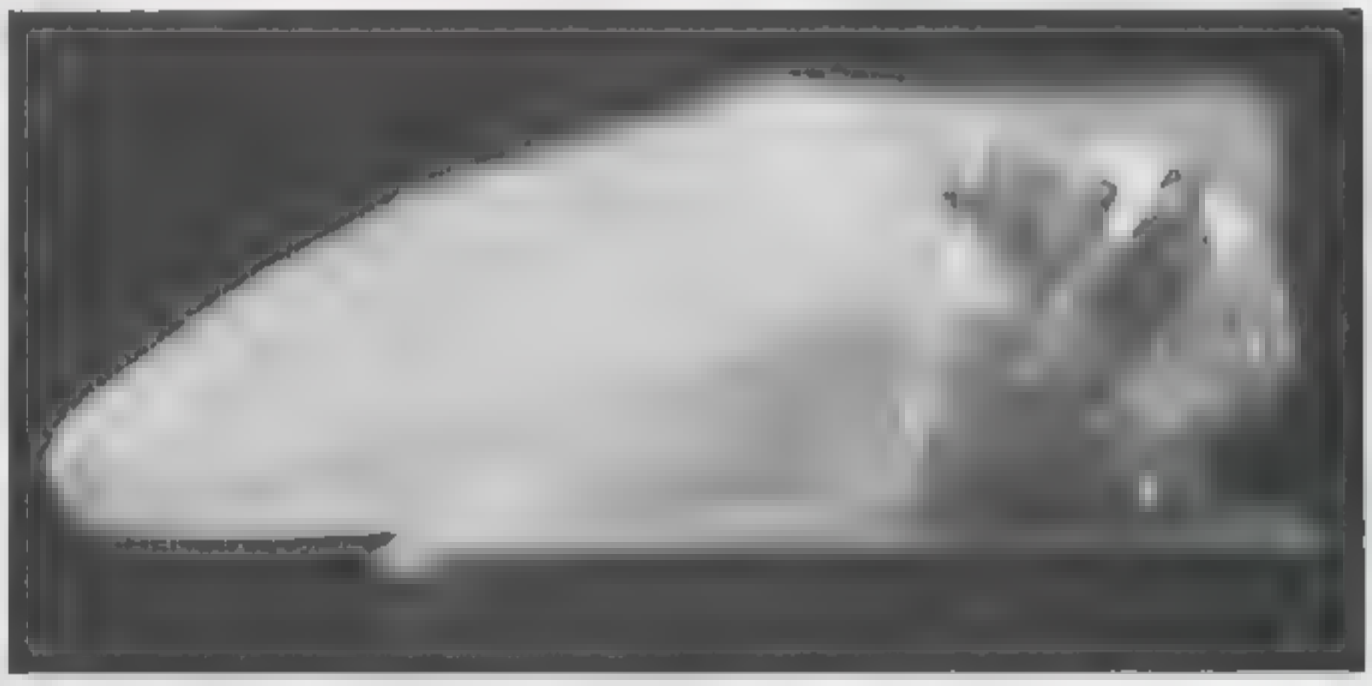
Some of the most attractive metamorphic rock has been created by directed pressure, that is, pressure acting in a specific direction. This can cause rock to rearrange itself in multicolored bands, as minerals tend to orient in clusters of similar chemistry. The bands vary in color due to their mineral content, and each layer is usually dominated by a particular mineral. Quartz, for example, often makes up the white banding we see in metamorphic rock, and darker iron-magnesium minerals like hornblende tend to migrate toward each other. The result is light- and dark-banded rock.

If the stress being applied is uneven, the developing layers tend to bend, creating very attractive curving layers. The curving bands may be under so much stress that the rock actually folds back on itself. I'm sure you've seen such lovely zigzag banded rock as you drive past some road cuts, such as those near New York City.

There is an obvious direct relationship between the original rock type and what it becomes when subjected to metamorphism. For example, limestone becomes marble, while its impurities form stable minerals like garnet. If the rock is dolomitic limestone, it ends up as dolomitic marble, which is higher in magnesium than ordinary calcite marble. Such minerals as actinolite and tremolite may be the result. The limestone quarries in Northwest Connecticut are an excellent source of tremolite, good evidence of the effects of metamorphism on impure limestone.

If the original rock is sedimentary sandstone, it ends up as quartzite. Rock that was once gravel and is made up of rounded pebbles is called conglomerate or puddingstone. When heat and pressure cause the rounded pebbles to become angular, the rock is called breccia. Granite often converts to gneiss, a very attractive banded, patterned and colorful metamorphic rock. Remember, granite is high in quartz and feldspar with small amounts of iron-magnesium minerals like phlogopite and biotite mica. When granite is metamorphosed, these common minerals end up as light and dark bands. If the feldspar in the original granite is the strong pink variety orthoclase, the gneiss can have a lovely pink hue to its salt-and-pepper appearance.

Shale, a sedimentary rock formed from mud, is often rich in mica. It will end up as schist. And under certain intense directed conditions, shale may develop into slate, a gray rock occurring in exceptionally thin layers that parts easily and can be used for roofing, flagstones, stepping stones, and the like. Wales is a well-known source of slate, since the mountains in that country are intensely metamorphosed. I was fortunate to visit a couple of slate quarries there, including one at which my grandfather worked as a slate loader.



A lovely yellow sapphire crystal from Sri Lanka could be faceted into a fine gem

A type of rock that is low in silica and very high in iron-magnesium minerals is called ultra-basic rock. It lacks quartz and is rich in olivine and related minerals. As a metamorphic rock, it can end up as serpentinite, a rock that has potential for artists. Serpentinite can phase into nephrite jade! The fibrous mineral asbestos, often associated with vesuvianite and lovely grossular garnet, is also a product of metamorphic ultra-basic rock.

Schist results from the change in sediments high in mica and related iron magnesium minerals. Under stress, it develops as a micaceous mass with a sparkling surface due to the mica flakes. Schist often ends up with lovely, discrete mineral crystals of one or more species that develop from its impurities. The better known minerals found in schist are staurolite and the more common almandine garnet, a dark-red iron aluminum silicate.

Almandine is not normally a gem mineral, but it is certainly an important study and display mineral, as it is usually found as textbook dodecahedral crystals. Garnet that looks like the perfect drawings in mineral books can be exceedingly abundant in schist deposits.

The Stikine River schist deposit near Wrangell, Alaska, is probably the best-known source of abundant quantities of collector almandines, both loose and locked in a schist matrix. Most are textbook perfect and fall within the range of an inch across. Their perfection suggests the schist in which they developed did not inhibit their growth at all. This is typical of many crystallized species found in metamorphic environments.

Garnets are found in a variety of rock types, including pegmatites and granites, but the most common variety, almandine, is abundant in some schists. Mineralogy books list more pegmatite occurrences than metamorphic sources, but that's mainly because pegmatites tend to produce more valuable gemmy garnet crystals, usually grossular associated with other choice gem minerals. Almandine garnets in schist tend not to be gemmy, so they are less valuable.

Still, the more common sources for garnet are metamorphic. It is found as euhedral crystals in mica schists, chlorite schists, and metamorphic rocks rich in amphiboles. The huge garnet deposit on Gore Mountain in New York, which was worked for years, formed in an amphibole. The huge red almandines there occur in a black hornblende schist.

Some of the largest almandines ever found have come from near Salida, Colorado. The Calumet Mine produced choice 4- and 5-inch-diameter textbook crystals in a chlorite schist. The chlorite here also formed in euhedral crystals to several inches long, usually in tight clusters on a fibrous chlorite matrix. The calumet deposit is actually a skarn, so it is localized. This is not unusual, though almandine garnet also occurs frequently in regional metamorphic areas.

A number of classic deposits in Europe produced fine specimens of garnet in schist. Another excellent almandine deposit that is still producing is the Roxbury, Connecticut, schist deposit on Greene's Farm. Collectors can still go there and collect for a small fee. The schist there is also rich in staurolite.

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Staurolite is a silicate that is not particularly popular with collectors. It normally occurs as a relatively dull brown mineral that is chemically complex. Both single and intergrown crystals are common in some schists. During metamorphic action, staurolite forms by packing up iron, zinc, magnesium, aluminum, silicon, oxygen, and the hydroxyl radical. It tends to develop a monoclinic form, but frequently pseudomorphs in the orthorhombic system.

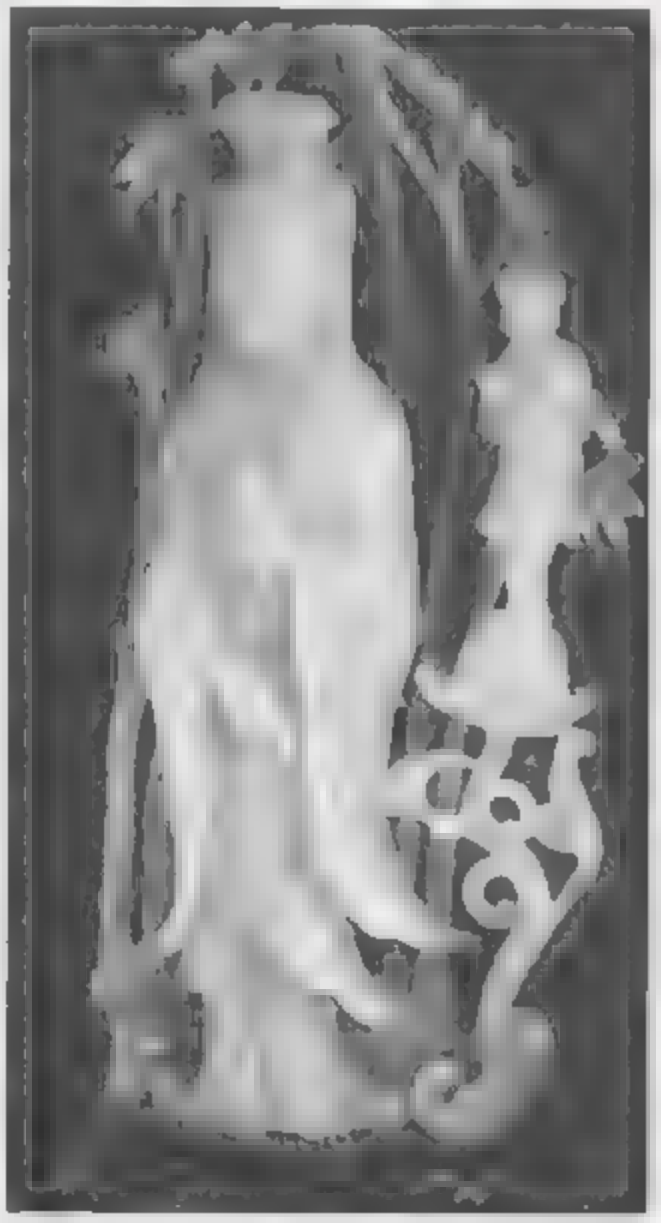
The more attractive staurolites are the twins, penetrating each other either at a 60-degree or 90-degree angle. The right angle twins look like natural crosses. This form gives the specimens their mineral nickname "fairy crosses." While the staurolites are quite abundant in a number of places, the better-looking specimens come from Georgia. The schist matrix is easily removed, and clean, sharp crystals are common.

Another common mineral seen in metamorphic deposits, particularly those involving limestone, is chlorite. This is a mineral that seems to sweep up all the iron, manganese, magnesium and aluminum remaining unattached as metamorphic action draws to a close. It is a low-temperature mineral and is often found coating other minerals that crystallized earlier.

There is a problem with chlorite and its name, which is suggested by the mineral's green color. The usual practice is to use this name to describe any green micaceous mineral in near-microcrystals coating feldspar and other minerals. The Swiss deposits produce lovely adularia crystals, many of them twinned, and many are coated with a green mineral usually called chlorite.

The problem is that a couple of minerals fit the description for chlorite. One of them so closely resembles chlorite that it is named chlloritoid. The second problem is that chlorite is also the name of a mineral group. Suffice it to say that when you see a micaceous rich green mineral on a specimen from a metamorphic deposit, you are probably looking at a member of this group, and unless you can X-ray the suspect you should call it chlorite.

The rare mineral clinochlore usually occurs as a green mineral. It's a perfectly lovely and diligently sought species that forms very attractive, and sometimes large, green, foliated, or sometimes tabular, crystals. Well over 100 years ago, the metamorphic deposit at the Tilly Foster Mine in Brewster, Putnam County, New York, produced stunning 2-inch crystals of clinochlore with very fine chondrodite and magnetite. When I visited the mine in the



This lovely jade objet d'art was carved in China and is displayed at the Lizzadro Museum in Elmhurst, Illinois

1950s, it had been turned into a junk car storage area.

Lovely clinochlores also have been found in some Swiss alpine deposits, Italy's Ala Valley, the Cedar Hill quarry in Pennsylvania, Lowell, Vermont, and other metamorphic deposits. But the most unusual clinochlore is far removed in physical appearance from specimens found at any these deposits. We call this variety of clinochlore kammererite.

Not all members of the chlorite group are green and micaceous. Kammererite is clinochlore with a stunning, deep violet-red color due to its chromium content. The finest crystals of this lovely display mineral can reach an inch long. Specimens are generally covered with tightly clustered small crystals on matrix and are very showy. The best of this species come from Kop Dag, near Askale, Erzincan Vilayet, Turkey.

Magnetite is a very common mineral in some metamorphic schists, such as at Chester, Vermont. It is common in skarns and other rocks that have been metamorphosed. It usually forms sharp octahedrons in these altered rocks, usually in chlorite or mica schists. Obviously, these crystals were able to grow due to migration of the iron oxide molecules during the metamorphic process.

The lovely blue-bladed mineral kyanite is very common in metamorphic deposits. This lathelike mineral occurs in a variety of regional metamorphic horizons, melding mica schists, gneisses, and complex eclogites, which are closely related to the rock types that produce diamonds.

Kyanite usually forms in long, flat blades. Its hardness is unusual in that you can scratch it along its length, but you can't scratch the same crystal across the short face. This is indicative of variations in bonding, with very strong bonds vertical to the length of the crystal and very weak bonds parallel to the length.

Some of the world's finest kyanites have come from near St. Gottard in the Swiss Alps. Most often embedded in schist, the kyanite is associated with metamorphic staurolite. Early American deposits of kyanite include Chesterfield, Massachusetts; Judd's Bridge, north of Derby, Connecticut; and Litchfield, Connecticut. These areas did not produce the quality of kyanite found in Brazil and elsewhere.

Brazil has been a source for some of the finest blue kyanite in recent decades. Sao Jose de Safira, in Minas Gerais, has produced some of the largest kyanites ever found. They often exceed 8 inches in length and have a fine blue color. Gem kyanite has come from another Brazilian source, Vitoria da Conquista, Minas Gerais.

Corundum, one of the more important gem species, commonly occurs in metamorphic environments. Collectors and dealers who specialize in gems are very familiar with the marvelous corundum gems ruby and sapphire. They are very often found in metamorphosed rocks or in alluvium derived from such rocks.

The great gem island of Sri Lanka is a source of fine sapphire. Rough gem crystals are found in gravels assumed by most to have come from an original metamorphosed source. This island is one of the classic major gem sources and is still producing a huge variety of gem species.

The common rubies you will most often see for sale at shows are the bright-red hexagons from Mysore, Karnayaka, India. These stubby simple hexagons occur in a micaceous schist. While most of the crystals are not clear gems, some are cut en cabochon and show a nice six-ray star effect due to needle rutile crystals oriented along the axes of the hexagon.

The rubies from several sources in Southeast Asia are much gemmier. The classic source is Mogok, Upper Burma, where bright gem rubies and, sometimes, nice blue sapphires are found in white marble, a metamorphic rock. Some of the world's finest pigeon blood rubies have come from this renowned source.

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Lately, the Mogok sources have been challenged by a deposit at Luc Yen, Vietnam, and another Myanmar deposit at Mong Hsu. These sources are also metamorphosed limestone (marble) and yield quantities of choice to good red ruby crystals. To produce these aluminum oxide gems, the metamorphic marble has to be in close association with rich aluminum sources, usually an igneous rock source.

Rubies are more common than sapphires. There are several places in America where you can hope to find this red mineral. The famous Franklin, New Jersey, zinc deposits are locked into a metamorphosed limestone, which on rare occasion yields nice, red, no-gem ruby crystals. And in western North Carolina, collectors can dig for a fee to find small ruby crystals in stream gravels.

Some years ago in Tucson, during the show season there, an amateur collector bought a large corundum crystal for a few dollars. It was supposedly from North Carolina and supposedly worth millions of dollars. This became an interesting exercise in using publicity to promote something. Experts from the Smithsonian Institution soon judged the crystal to have a value of a few hundred dollars at best.

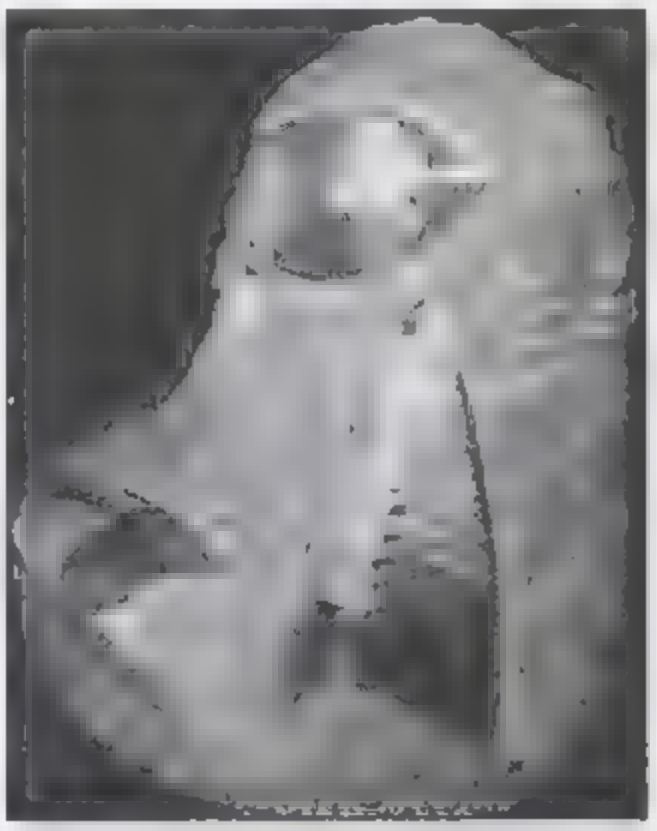
Metamorphic rocks are not often an exciting source of distinct fossil remains. The heat, pressure, and invading chemistry pretty much destroy most organic remains. But in some low-temperature deposits, some fossils can survive.

In Morocco, some very spectacular dark-gray marble rocks, probably the result of low-temperature contact metamorphism, hold myriad nautiloids and segmented, tapering, long baculite fossil remains. The nautiloids tend to have a brownish color, while the baculites are black and white in contrast to the gray matrix. Skilled workers chisel away enough of the host rock to expose the fossils, ancestors of today's octopus and squid. Slabs large enough to be used as tabletops, showing literally dozens of baculites, are sold. The fossils tend to be more or less parallel to the rock and, if properly prepared, make a spectacular display rock. At major shows, it is not unusual to see slabs of this fossil-endowed rock measuring 3 or more feet across. These slabs are prepared for use as tabletops, paneling, and even carved objets d'art.

It may interest readers to know these display fossils are prepared using air hammer chisels, which are notorious for creating clouds of rock dust, shrouding the workers in unhealthy rock particles.

Without the action of metamorphism, we would not be able to enjoy aesthetically pleasing carvings in jadeite or nephrite, both of which are products of the metamorphic action of heat and pressure. The ancient Chinese called these minerals Yu, a general term that included anything resembling jade.

Undoubtedly, the finest jade carvings have come to us through the centuries from China. Artisans there will work their entire lives to turn out just one intricate creation of delicate beauty that symbolizes a god or goddess, flowers, creatures of nature, or some human quality we all strive to emulate.



Fossils: shells of the nautiloid are found in a brown schistose in Morocco.

Nephrite is the more common form of what we call jade. "Jade" is a universal term that is applied to both jadeite and nephrite. Nephrite is usually thought of as green, though it can be a range of colors. Unlike jadeite (which is an actual mineral species with a sodium, aluminum, iron silicate composition), nephrite is a mixture of at least two minerals, actinolite and tremolite. These minerals develop in long fibers, which intergrow to form tough nephrite. These fibers give the stone a toughness that is hard to overcome. They also preclude such difficulties as cleavage and fracture, so carving nephrite is free of such pitfalls.

By following the nephrite "float" in streams coming from the eastern mountains of China, the Chinese discovered the source of nephrite in the Kuen Lun Mountains, a huge vein that ranged from 20 to 40 feet thick. The vein was wedged between two metamorphic rock types, gneiss and schist. The source was vigorously mined and the material brought to the carving centers of China.

Vast quantities of nephrite are found in northern Alaska and western Canada, today's great suppliers of this lovely gem. Huge boulders have been found in situ in central British Columbia and very active mining is ongoing here. The Alaska find is scattered around what is called Jade Mountain, but mining here does not reach the intensity seen in Canada.

In Siberia, near Lake Baikal, is an amazing deposit of nephrite. On one of my visits to the Gems Museum in Moscow, I was shown large chunks of fine green nephrite reported to have come from a solid vein of material 3 feet thick that extends for hundreds of feet along an exposed mountain face. As transportation is such an iffy thing in Siberia, this deposit awaits its potential as a marketed material.

Ancient Western Hemisphere cultures used nephrite, particularly in Mexico, where the Aztecs mined the stone in what is now Guatemala. It was also mined in South America by the Incas. The early Maori culture in New Zealand used nephrite extensively for carvings, tools and weapons. Even today, visitors to that great country can obtain modern nephrite works done by the Maoris.

Jadeite, unlike nephrite, is a single chemical compound. It is as hard as quartz and can accept any one of several chromophores to give it color. Chromium produces a lovely emerald green material, iron can effect a yellow to reddish color, and the lovely and rare violet color of jadeite is due to manganese.

Jadeite is found in commercial quantities only in one area of Upper Burma. It has been found near the benitoite deposit in California, but that source has little effect on the market.

In the Uru Valley in Upper Burma, there are four known veins of metamorphic rock, the largest of which extends at least four miles. All are mined diligently, while boulders that have weathered out in the distant past are also gathered from neighboring riverbanks. The Chinese were eager to obtain Burmese jadeite and established a trade relationship here centuries ago.

Recently, maw-sit-sit, a new form of what many consider jadeite, has been coming from Burma. The material is a mixture of two minerals originally identified as albite feldspar and jadeite, common products of metamorphism. Later studies have shown them to be two other minerals: common white natrolite and an unnamed green mineral. The white and rich green minerals mix to create a lovely green and white pattern throughout the rock. Maw-sit-sit has been around since 1963 and takes its odd moniker from the place it was found.

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Earth's Crust *from page 78*

While nephrite and jadeite have been very popular lapidary gems for centuries, one new metamorphic gem was discovered just over 35 years ago. Charoite comes from a remote metamorphic region northeast of Lake Baikal in Siberia known as the Maran Massive. The location was being studied by geologists from the Mining Institute in St. Petersburg. One of the colorful rocks they found was first thought to be cummingtonite, but studies revealed there was something special about the rock. It turned out to contain more than a dozen minerals, dominated by a lovely violet-colored complex species made up of potassium, calcium, sodium, fluorine, silicate. Named charoite, this rock was an instant success once it became available.

The violet or purple rock is beautifully patterned with streaks and blotches of other colors due to included minerals. As is typical of some metamorphic minerals, the charoite can be gemmy crystalline fibrous, or in random masses locked in the specimen. The outcrops where it was found are extensive, with at least 25 known deposits in the area. The problem, as with many mineral deposits in Siberia, is transportation. The region is so remote it takes three days' travel by boat, followed by several days' walk to get there!

When I was working with Moscow's Ocean Pictures and the University of Moscow on the video "Russian Gem Treasures," we met the geologists who found and studied charoite. They had huge masses of the material at the Institute, including highly polished 2-foot slabs. They were still studying the identities of some unknowns in the rock, which they judged had formed at least 15 kilometers deep in the crust. This is well below the zone subjected to weathering and right where you would expect metamorphism to dominate.

The plan was to follow "Gemstones of Russia" with a second video "Gemstones of Siberia," which would have included work at the charoite sites. However, we were unable to get the financing needed to do the project, so the charoite deposits, among many other interesting mineral and gem localities in Siberia, remain unpublicized.

Clearly, metamorphic environments yield a far greater variety of species than do sedimentary formations. This seems logical since metamorphism can affect any existing rock and have access to virtually every common and rare element or chemical mix found in the Earth's crust. If you consider that heat, pressure and chemical invasion can attack any igneous rocks, sedimentary rocks, or previously formed metamorphic rocks, you can see that the chemical ingredients available to metamorphism are limitless.

GOLD AND GEM HIGHWAYS

ROADSIDE PANNING SITES IN SOUTH CAROLINA

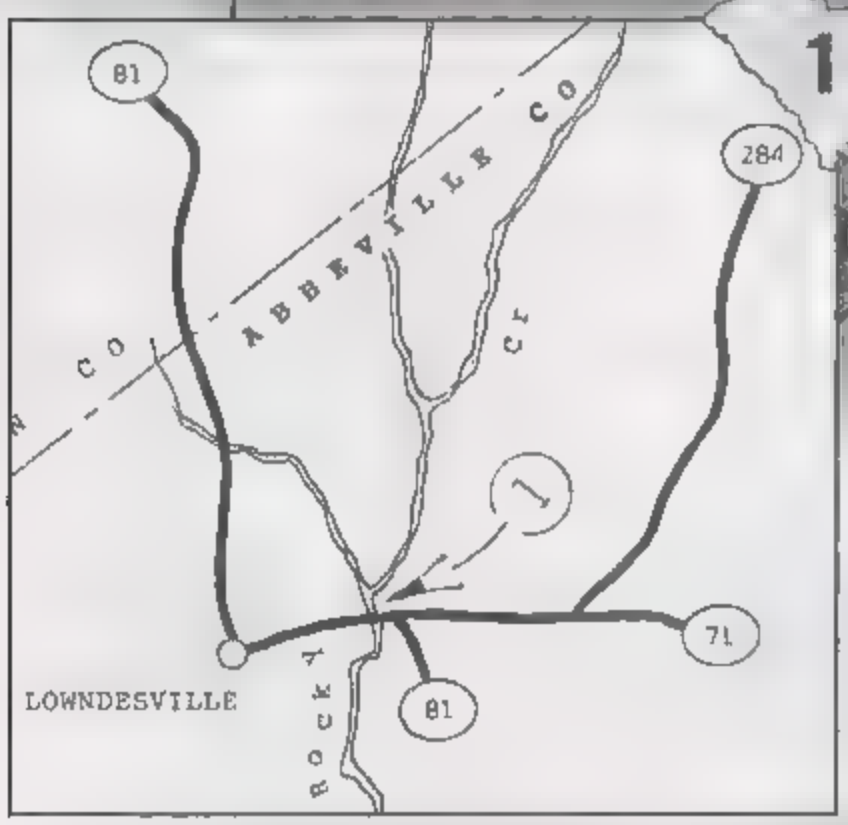
Part I: Abbeville, Aiken, Allendale and Anderson Counties

Story and Maps
by David and Clois Walker

This is the first in a series of six articles containing maps that indicate suggested panning and screening sites at South Carolina highway/stream crossings where appreciable finds have been previously reported in vicinity watersheds. The principles of erosion make it likely that minerals and gemstones have been deposited in river gravels, awaiting removal by a rockhound with a pan. This is a speculative study: whether conditions at these sites are conducive to panning activities and whether minerals can indeed be found have not been investigated.

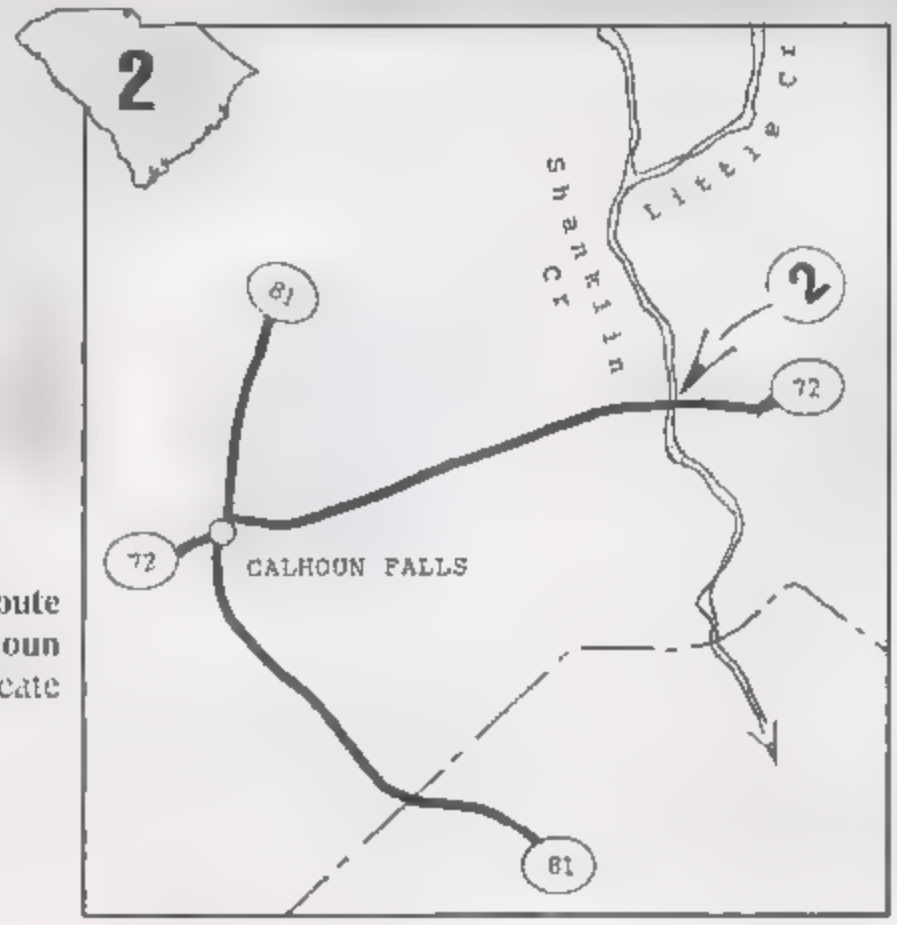
By confining operations within government-purchased highway rights of way, panners are spared the necessity of locating and obtaining permission from adjoining property owners. However government permission is given on a case-by-case basis. Visit the South Carolina Department of Transportation Web site, www.scdot.org/inside/engineering_directory.shtml to find the number of the local office that gives access permission and explains the extent of the right of way. Readers also run the risk of prosecution if they cross onto private land, whether purposely or unadvertently.

Remember to observe highway safety and environmental standards, such as parking only where designated, and using only a pan and scoop. The maps provided contain the most up-to-date information available to us, but it is advisable to consult a current state highway or county map when planning an outing, for overall orientation in the field and because highway designations have been known to change.



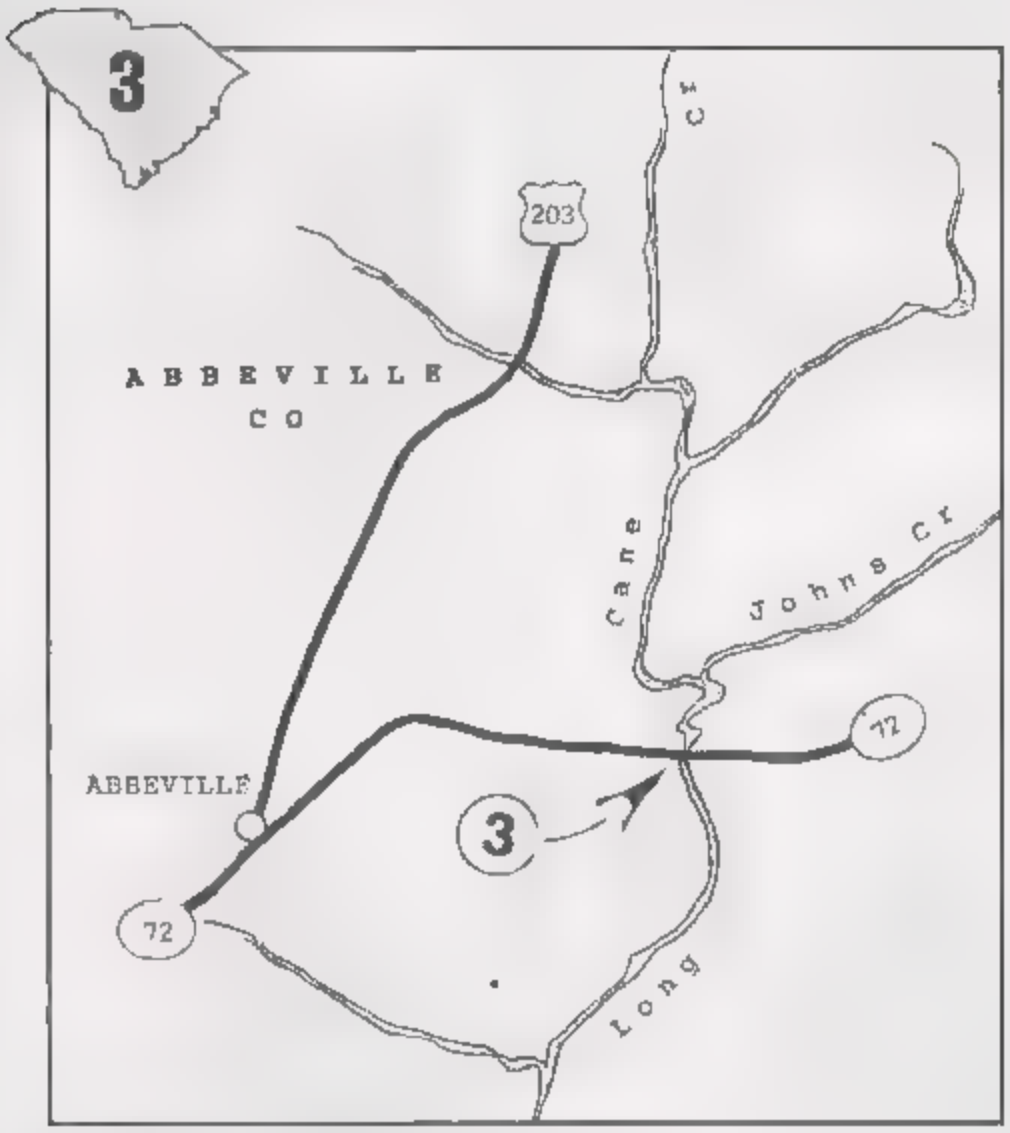
ABBEVILLE COUNTY (MAP SC1)

Site 1, **Rock Creek/state Route 71** crossing near **Lowndesville.** Vicinity finds include amethyst, corundum, garnet, gold, quartz and zircon.



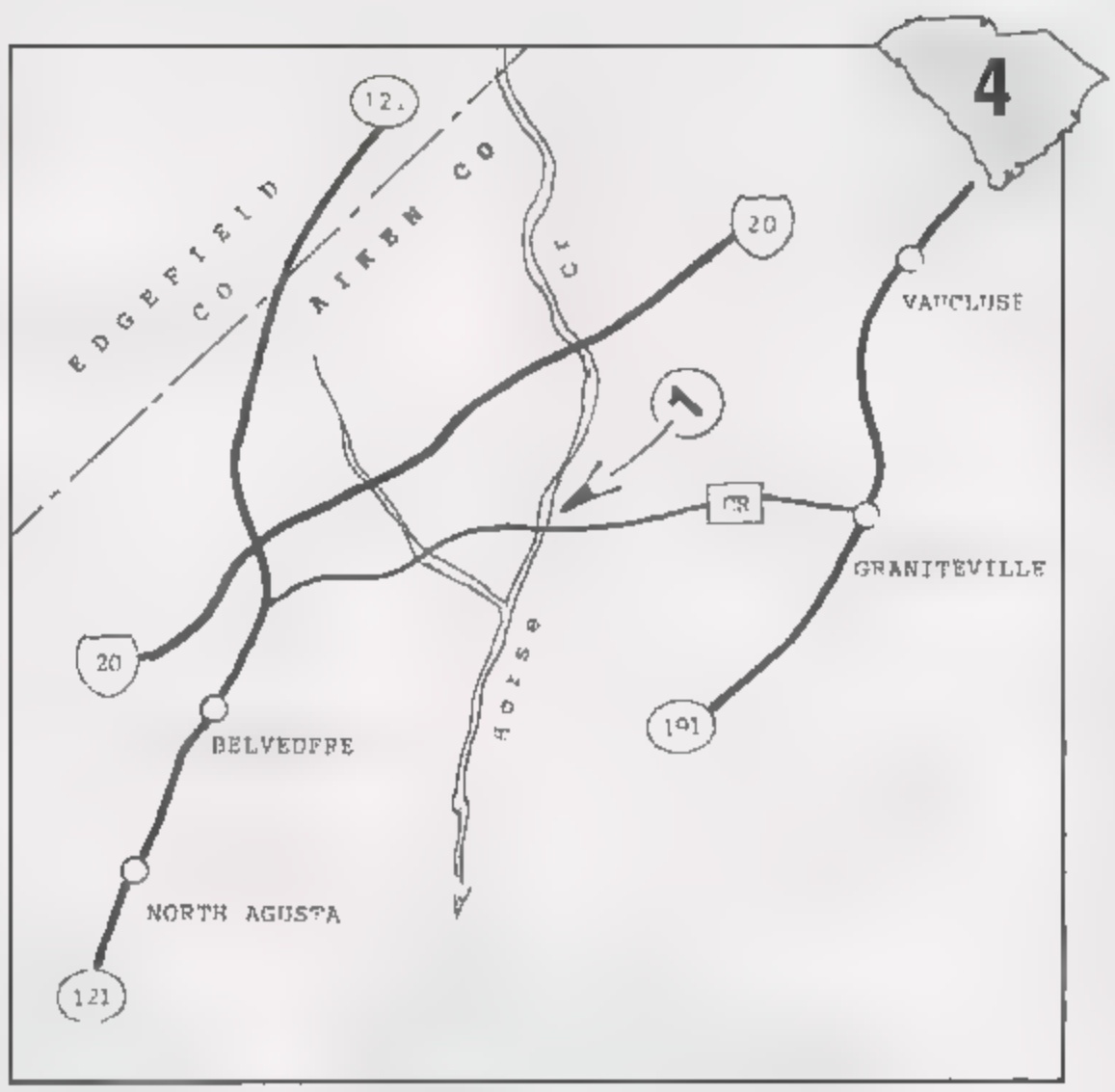
ABBEVILLE COUNTY (MAP SC2)

Site 2, **Little River/state Route 72** crossing near **Calhoun Falls.** Vicinity finds indicate gold potential.



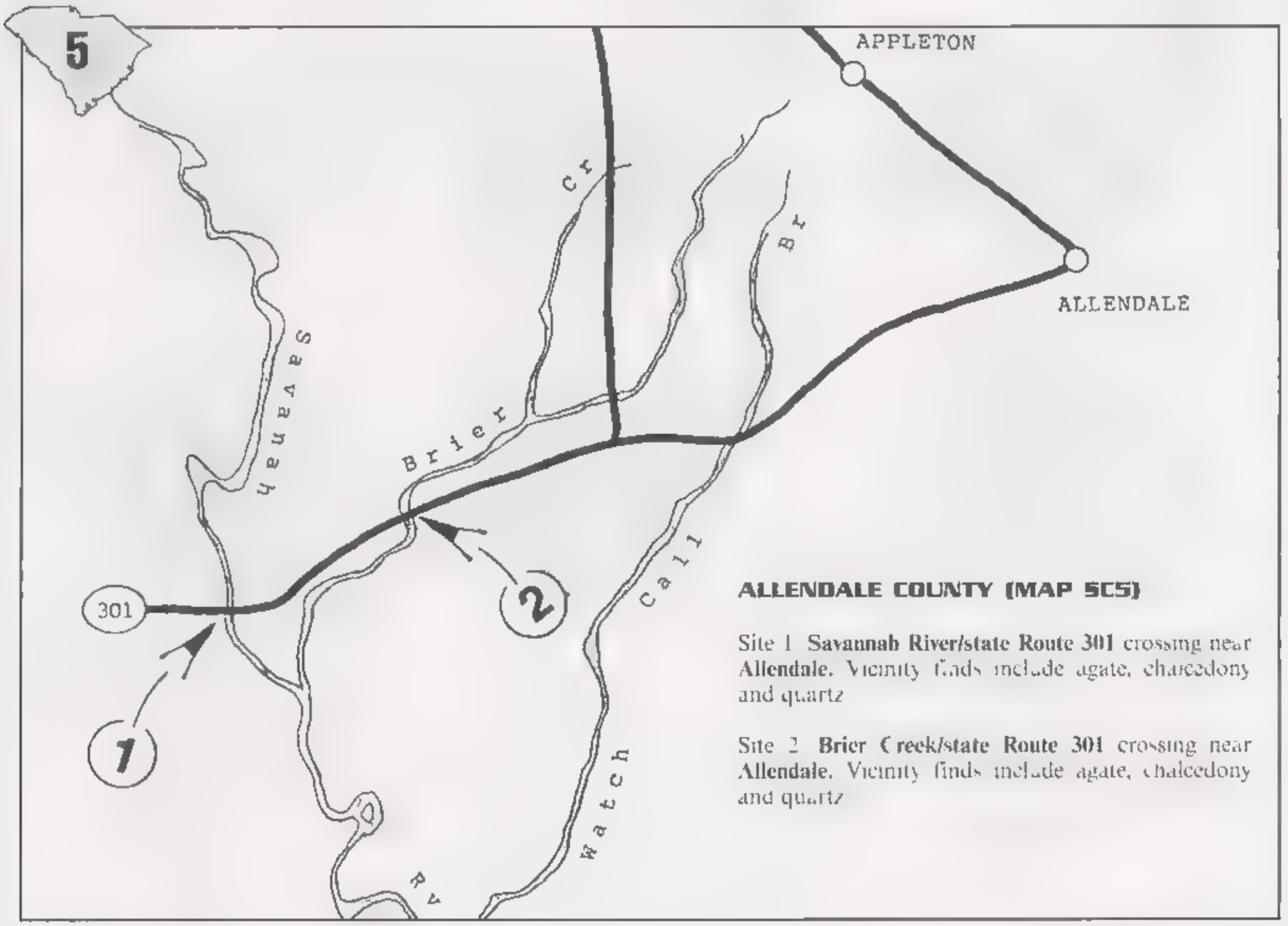
ABBEVILLE COUNTY (MAP SC3)

Site 3 **Long Johns Creek/state Route 72** crossing near **Abbeville.** Vicinity finds include amethyst and quartz



AIKEN COUNTY (MAP SC4)

Site 1 **Horse Creek/County Road** crossing near **Graniteville.** Vicinity finds include amethyst, chalcedony and quartz



ALLENDALE COUNTY (MAP SC5)

Site 1 **Savannah River/state Route 301** crossing near **Allendale.** Vicinity finds include agate, chalcedony and quartz

Site 2 **Brier Creek/state Route 301** crossing near **Allendale.** Vicinity finds include agate, chalcedony and quartz

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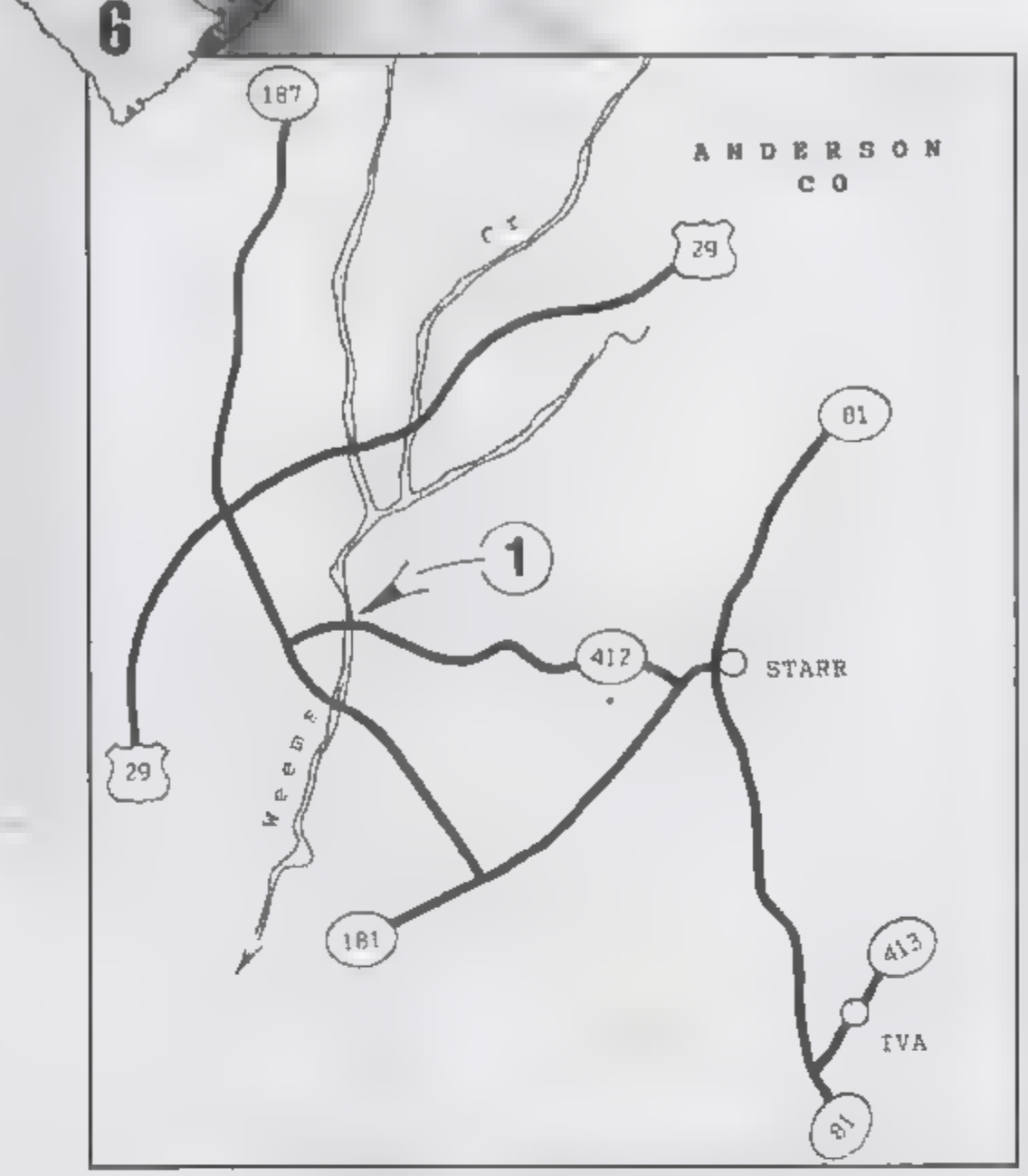
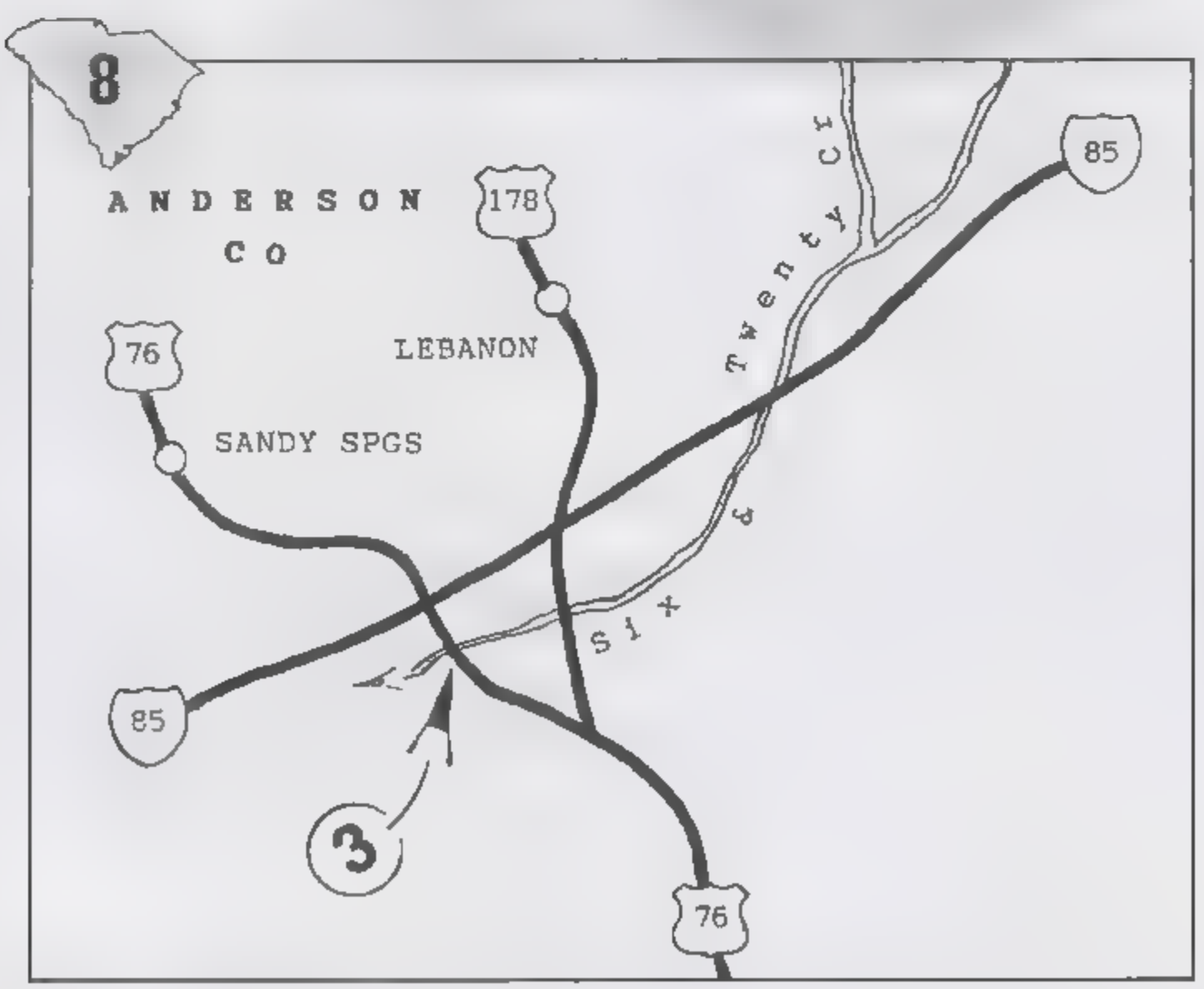


ANDERSON COUNTY (MAP SC6)

Site 1 **Weems Creek/state Route 412** crossing near **Starr.** Vicinity finds indicate beryl potential

ANDERSON COUNTY (MAP SC7)

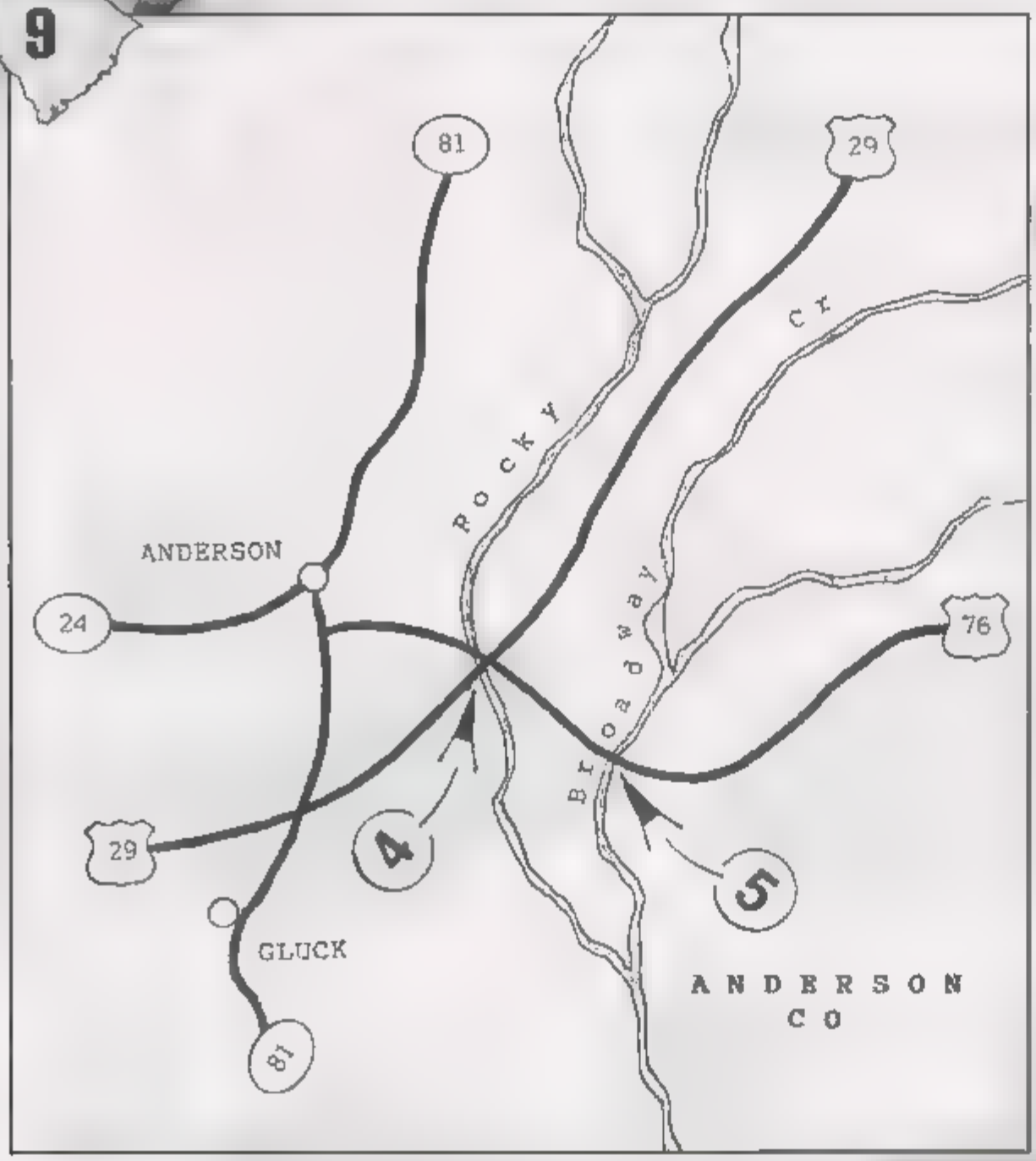
Site 2 **Savannah River/state Route 184** crossing near **Iva.** Vicinity finds include aquamarine and beryl



ANDERSON COUNTY (MAP SC8)

Site 3 **Six and Twenty Creek/U.S. Highway 76** crossing near **Sandy Springs.** Vicinity finds include garnet and quartz

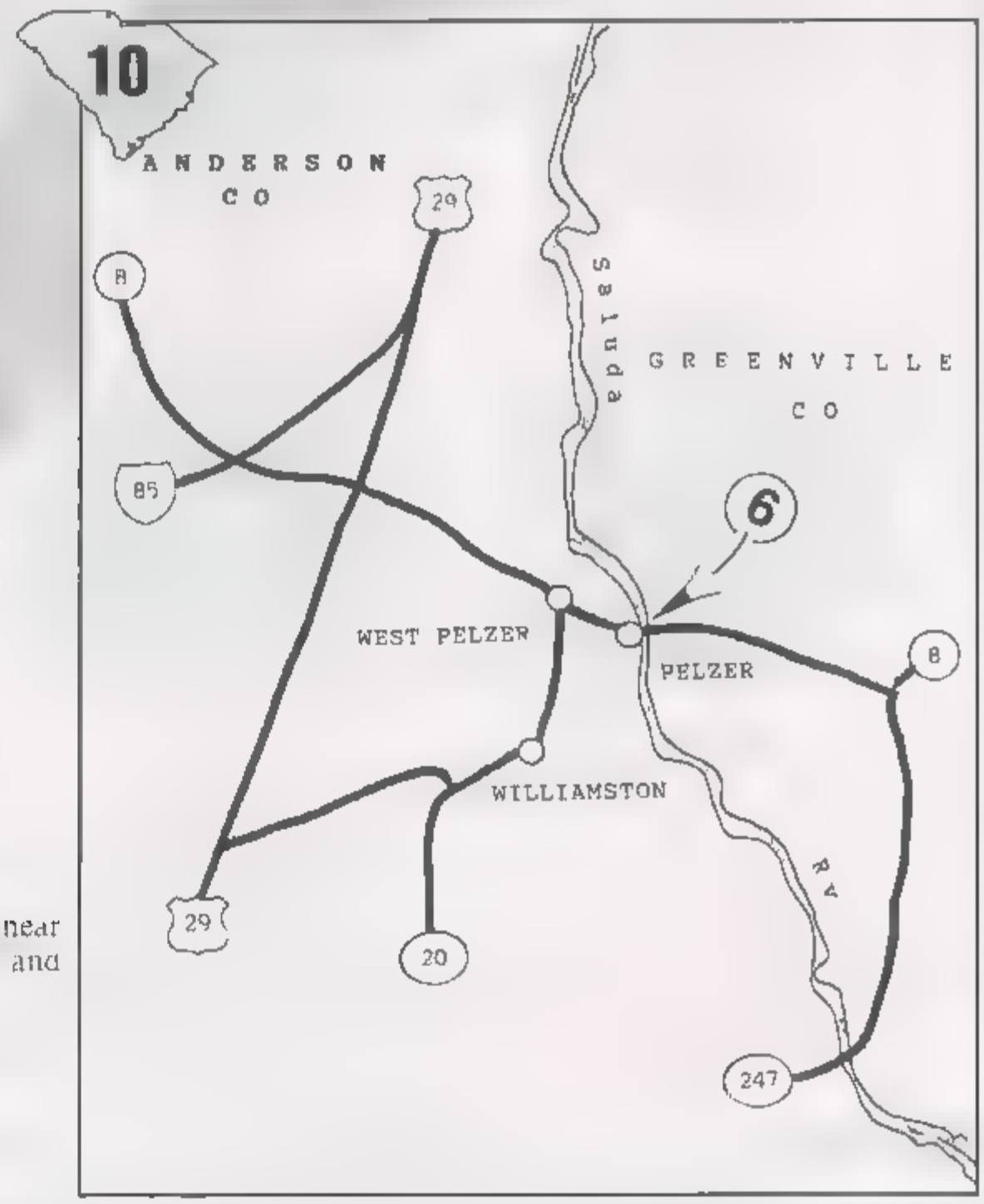
continued on page 38



ANDERSON COUNTY (MAP SC9)

Site 4 **Rocky River/U.S. Highway 29** crossing near **Anderson.** Vicinity finds include aquamarine, beryl, garnet, gold, quartz and tourmaline.

Site 5 **Broadway Creek/U.S. Highway 76** crossing near **Anderson.** Vicinity finds include beryl, garnet, gold, quartz and tourmaline.



ANDERSON COUNTY (MAP SC10)

Site 6 **Saluda River/state Route 8** crossing near **Pelzer.** Vicinity finds include aquamarine, gold and tourmaline.

PROJECT

Making Gems Into Pens

A New Outlet for the Lapidary

Story and Photos by Jim Perkins

Pen making was first introduced to woodworking hobbyists. However, it recently became a hot new facet for the lapidary hobbyist with the introduction of Tru Stone pen blanks, which are available in 12 different reprocessed gem materials.

When I first explored pen making, I found most of the required tools were already a part of my workshop. If you don't have exactly the same tools I use, it doesn't matter, some hand tools could work equally as well. I only had to purchase a pen press, which I find works much better than trying to use a C-clamp, as well as the pen component kits and pen blanks.

Since the process requires working with some power tools, I recommend that newcomers seek the guidance of someone who has experience with such equipment. Every lapidary club I know of has a machinist or engineer as a member who will be able to advise on proper shop methods and safety, which is an individual responsibility.

Start up pen kits can be purchased that include the required mandrels and drill bit. Drilled blanks are also available. The components I used for this project were the chrome flat-top American twist

Obtain a pen blank and component parts for the style of pen you wish to make.

PEN KIT SUPPLIERS:

- Berea Hardwood
  www.bereahardwoods.com
- Craft Supplies USA,
  www.woodturnerscatalog.com

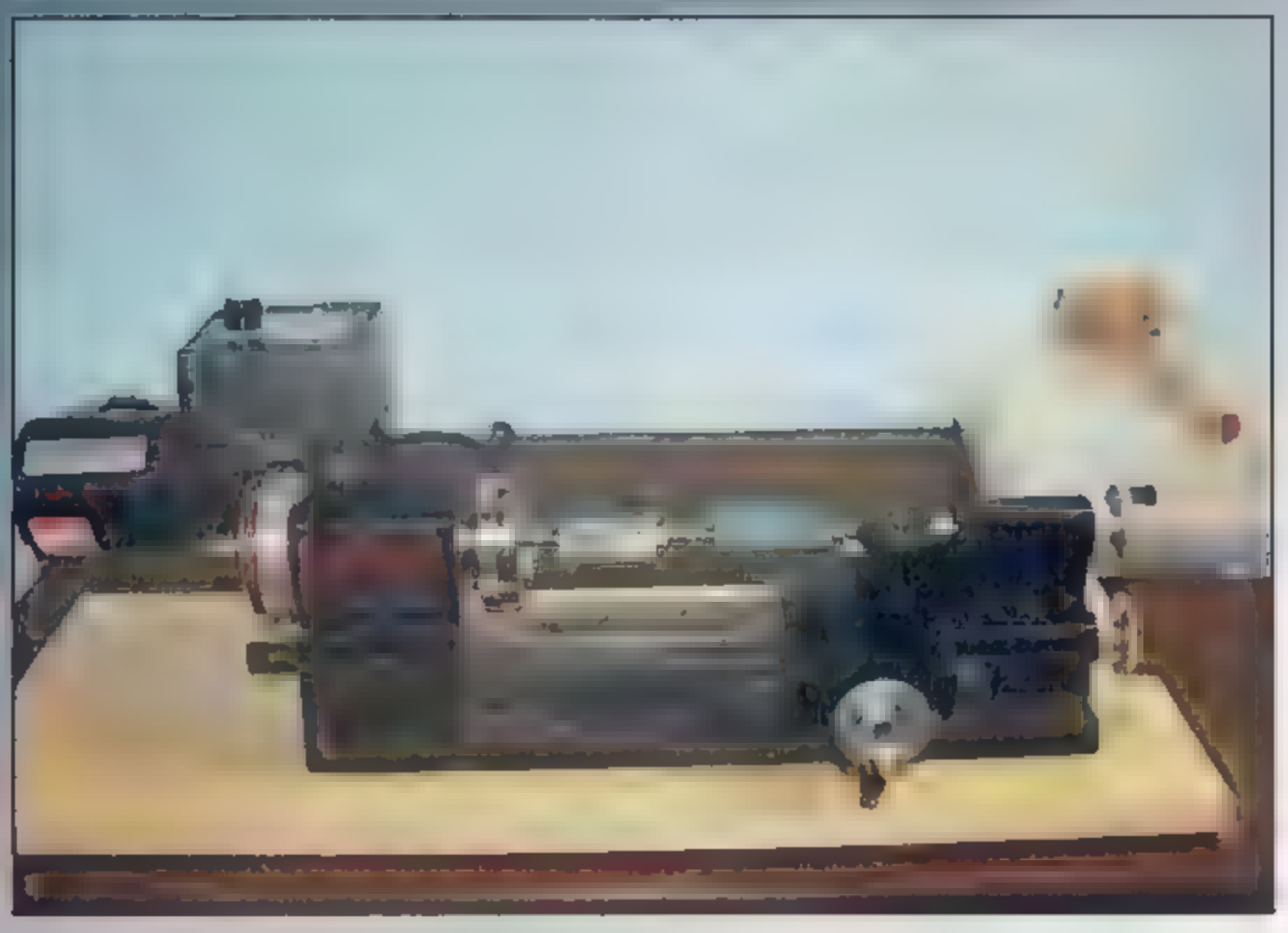
TOOLS:

- 6-inch scale for measuring
- Sharpie marking pen
- Bone saw, jeweler's miter saw, or lapidary trim saw
- Drill press and vise
- Wood lathe or jeweler's lathe
- Disc sander with miter gauge
- Pen press or C-clamp
- Other tools as recommended by your pen kit

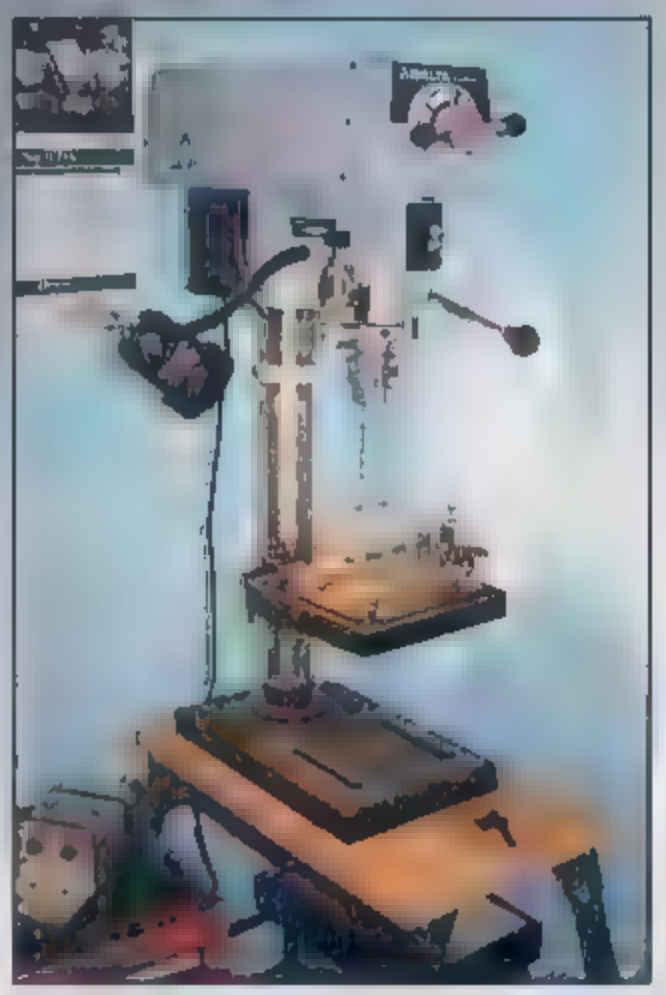
SUPPLIES:

- Five minute epoxy
- Emery cloth
- Small RAT round file

Use a bandsaw to cut the pen blank to length



A Sherline jeweler's lathe is ideal for turning the pen blanks.



Drill the pen blanks with a standard drill press

Turn the pen blank on a mandrel supplied by the pen kit manufacturer

pen (416-B-CHR), a mandrel rod (MANDREL-B), the 1-B pen tube bushing, and an "O" drill bit from Berea Hardwood; and an undrilled Tru-Stone blank, a plastics wet sanding kit (084-1000), and HUT Ultra-gloss polish (089-0106) from Craft Supplies USA. Most pen makers will produce multiple pens for sale or for gifts, so suppliers usually offer a small discount on quantity purchases.

PREPARING THE MATERIAL BLANKS

I cut the blank for the top of the pen to a length of 1 ¾ inches, which leaves some of the brass tube exposed, but this eliminated the need to use a parting tool on the lathe to make room for the pen's center ring. I used the other brass tube as a gauge and cut the bottom pen blank slightly longer than it. I drilled both blanks using an "O" drill bit on the drill press, holding the blanks in a drill press vise.

I roughed up the surfaces of the brass tubes with sandpaper and cleaned them with alcohol. Then I applied five-minute epoxy to the inside of the hole and the outside of the brass tube and inserted a tube into each blank. If any epoxy works into the inside of the brass tubes, I use a toothpick to wipe it out, as the inside of each tube must be completely clean. After the epoxy has dried, I use a round file to clean out any epoxy I missed with my toothpick.

TURNING THE BLANKS

Make sure you properly identify each bushing and how it should be placed on the mandrel in relationship to the blanks. If you are not sure, compare it to the component part in the pen kit that fits on that part of the pen. For example, the pen finial bushing will be the same diameter as the pen finial.

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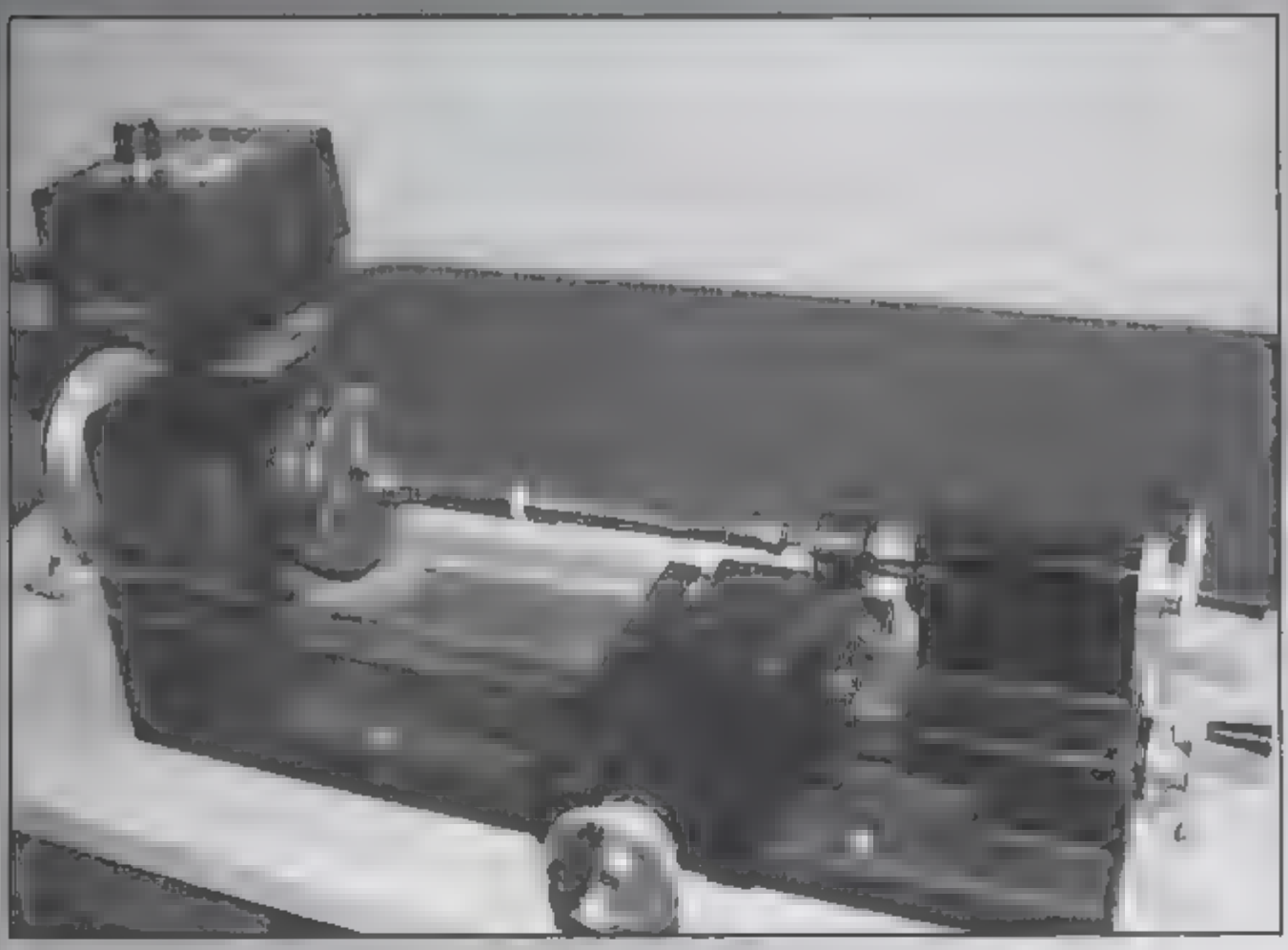
Making Gems Into Pens *from page 41*



Sand and polish the finished pen blanks on the lathe using the sanding kit

Use the pen press to assemble the kit parts.

The center ring bushing is longer than any other bushing because it will cover the exposed part of the brass tube during turning. The bushing will also act as a size gauge for turning the blanks to proper diameter.

Make sure you leave a small amount of material to be removed during the sanding and polishing process. Initially, I turn the blanks until they are completely round and leave 1/64 inch to 1/32 inch excess on the diameter. I remove the blanks and, using a miter gauge to hold the blank perpendicular, I use a disc sander to sand the pen blank until the end of the brass pen tube is shiny. This squares off the end of the pen blanks perfectly to the centerline of the tubes because I have turned the outside diameter concentric to the inside diameter. Be careful not to sand away too much of the brass tube's length because the pen will not function properly if it is too short.

continued on page 44

Pens *from page 42*

I find this method better for squaring the blanks than using a barrel trimmer. Once the blanks are square, I return them to the lathe and turn them to their finished diameter, using the bushings as my gauge. I leave just enough material for sanding and polishing.

FINISHING

Tru-Stone is natural stone that has been pulverized and then reconstituted using resin. It looks just like the original stone but it can be machined using standard high-speed steel tools rather than diamond tools. I have found I get the best finish using the same type of sanding and polishing materials I'd use for any resin type material rather than wood turning materials. Keep the sanding and polishing media wet with water and apply the final polish with paper towels.

ASSEMBLY

To assemble the upper pen blank, use your pen press to press the center rings onto the bottom of the top blank. Before going any farther, make sure the twist mechanism will slide through the top blank brass tube without getting stuck. If it is a tight fit, don't force it. Remove the mechanism and, using your round file, gently file the brass tube's inside diameter. Keep trying the mechanism until it slides through completely without binding anywhere.

Next, press the clip bushing into the top of the twist mechanism and press this assembly into the top of the upper pen blank until the clip bushing is flush with the blank. Hold the clip in place and thread the finial part to the clip bushing until it is tight, then set the top of the pen aside.

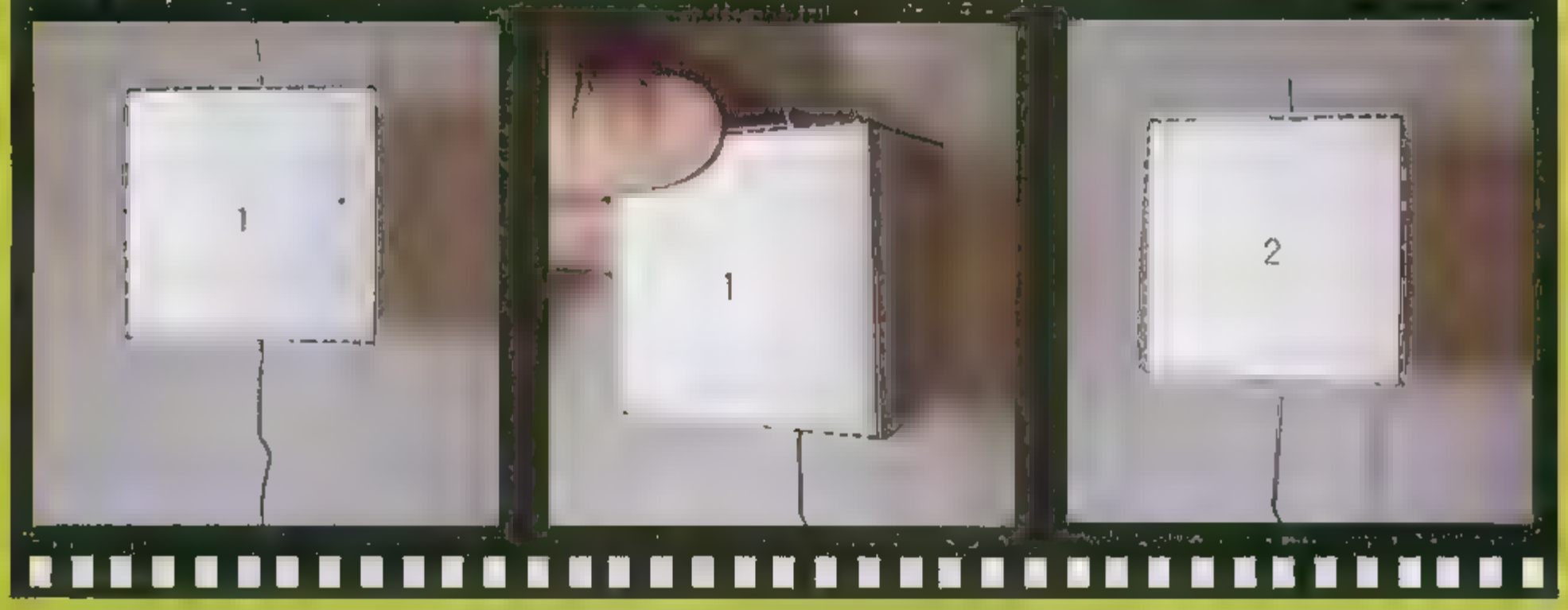
To assemble the lower pen blank, press the nib into the black nib holder and place the decorative blank on the top of the nib holder. Press this assembly into the bottom of the lower blank. Press the unthreaded end of the twist holder into the top of the lower blank.

Next, insert the pen refill with the spring into the lower pen blank and thread the twist mechanism in the upper blank onto the twist holder of the lower blank. When the thread bottoms out, torque it just a little so that the top doesn't start to unscrew if the pen is twisted counterclockwise. Now you can admire your work and show your friends.

If you have any comments or questions about this project, e-mail me at jim perkins@zoominternet.net or write to Jim Perkins, PO Box 1041, Medina, OH 44258.

ROCK & GEM

Make A Crystal Model, Part II



Rotate the cube on its axis to see its four points of symmetry

Let's use the paper cube model we made last month to get a better idea of what **symmetry** is all about

The **isometric** (cubic) crystal system has the highest symmetry of the seven crystal systems. Some common isometric forms are the **cube** (six faces), **octahedron** (eight faces), and **dodecahedron** (12 faces). The forms all have three **axes** of equal length at 90 degrees to one another. The simplest form is a cube, which has six square faces, all 90 degrees apart. A cube has three axes of **fourfold** rotational symmetry. We will use your cubic crystal model to try to make sense of these terms!

Hold your model vertically by the axis, and rotate it until you see the number 1 on the face right in front of your eyes. Now rotate it to the left until the number 2 is right in front of you. Other than the different number, the cube looks just the same. That means you have rotated the cube 90 degrees to a point of symmetry.

If you continue to rotate it, you will see a total of four faces. In **crystallography**, this is called "fourfold rotational symmetry." A circle is 360 degrees; when divided by four points of symmetry, each point must be 90 degrees apart.

Stick another wire axis through the center of faces 2 and 4 and rotate the cube. You will find four other points of symmetry at 90-degree intervals. You could stick another wire axis through the center of faces 1 and 3 and rotate the cube to find four points of symmetry on that axis. By the way, the three axes are named a1, a2 and a3.

I hope this visual aid helps the concept of fourfold rotational symmetry make sense. If not, take it again from the top, slowly.

GLOSSARY (Use your dictionary to look up other words you don't understand.)

axes plural of **axis**, a straight line about which a body or geometrical figure rotates or may be supposed to rotate, with respect to which a body or figure is symmetrical

crystallography a science that deals with the forms and structures of crystals

fourfold having four parts

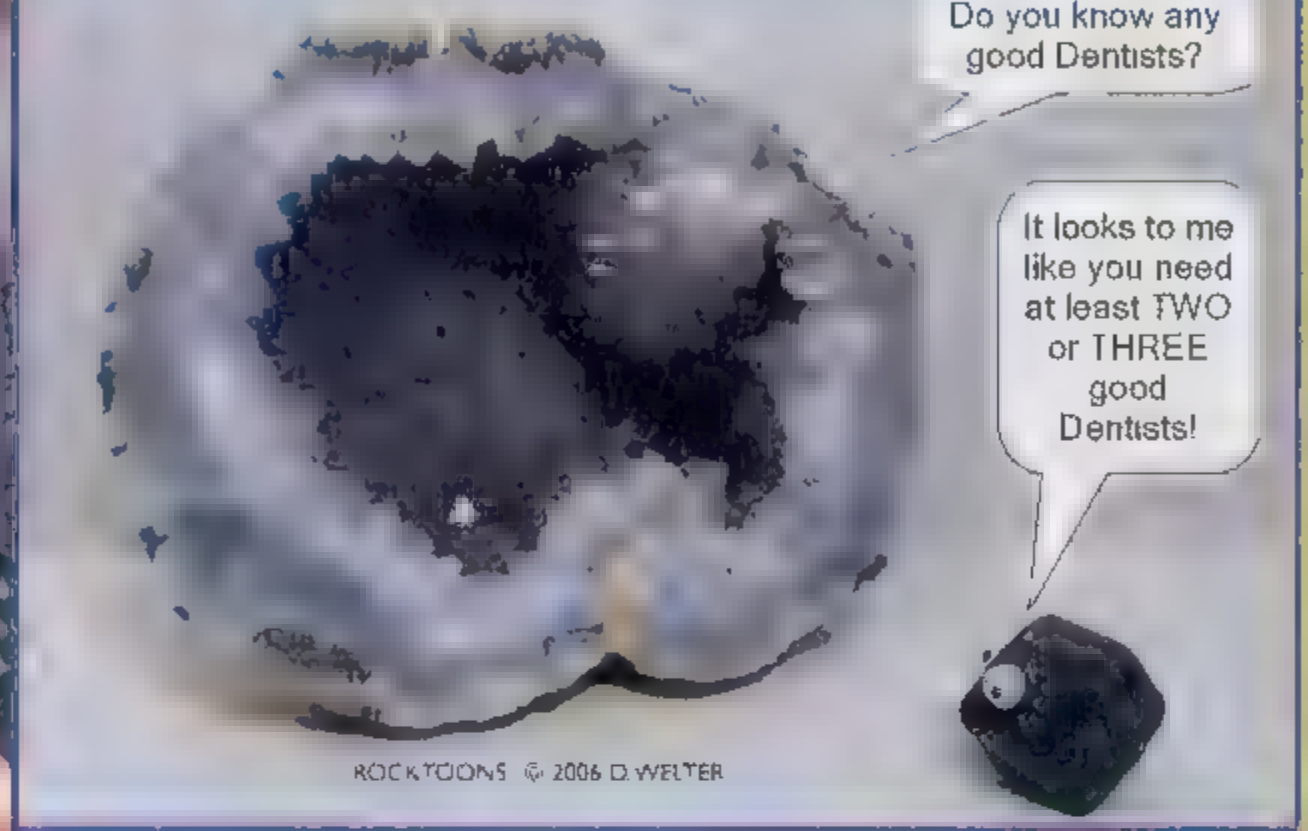
isometric a crystallographic system characterized by three equal axes at right angles

symmetry having the same size, shape, and relative position of parts on opposite sides of a dividing line

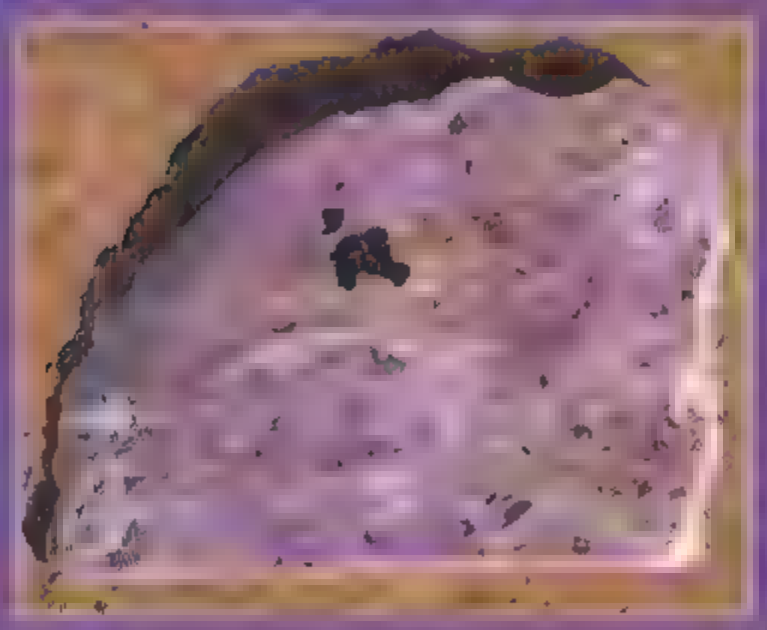
KIDS

by Shane Baker

Rocktoon



Charoite



Rock & Gem Kids Quiz

The *Rock & Gem* Kids Quiz contest is open to U.S. residents age 18 and younger. All these questions can be answered by carefully reading this column. Write your answers neatly on a postcard or 4X5 card and mail to **March *Rock & Gem* Kids Quiz, P.O. Box 6925, Ventura, CA 93006-9899.** Valid entries received by **Mar. 31, 2006** will be entered in a drawing from which five winners will be chosen. Valid entries must be the entrant's own work and must include the correct answers, the entrant's name, age and address, and the signature of a parent or guardian. Prizes are generously provided by the Arizona Mineral and Mining Museum Foundation.

1. Charoite is formed from an alteration of _____
2. Charoite's unusual chemical makeup combines _____ _____ _____ _____ and _____
3. Some common isometric forms are the _____ _____ and _____
4. An axis of _____ _____ shows four faces that are exactly the same.
5. The three axes of a cube are named _____ _____ and _____

FIELD TRIP

Kentucky Potato Geodes

The interiors of many of the geodes contain brilliant, clear quartz

Quartz Crystal Geodes South of Louisville

Story and Photos by Robert Beard

Geodes are always popular with collectors. Even people who say they have rock collecting, like my kids, will generally enjoy a geode-collecting trip if they can find some good geodes. I have found that the geodes with good terminated quartz crystals are the most popular with the people I have taken on collecting trips.

However, geode collecting can have its downsides. At some places, such as the Sheffler geode mine in northeastern Missouri, whose future is uncertain due to highway construction, geode collecting is hard work. Unless you are collecting surface scraps from previous collectors, you not only have to dig through overburden, you also have to chip, chisel and pound your way through solid rock to find the geodes. This becomes really hot work in the heat of summer, and especially messy work if it rains.

In other localities, such as the Black Dam geode sites along Clanton Draw in extreme southwestern New Mexico, which may now have access issues due to illegals crossing the nearby Mexican border, geode collecting requires going to a very remote location. You can pick geodes off the ground and from outcrops, but you have to watch your back to make sure neither a border crosser nor the Border Patrol is going to surprise you.

Other former-producing geode-collecting sites are now off-limits or difficult to access. I am aware of some road cut sites in Missouri that are closed to collectors, and I am sure that is the case in many other states, as well. Several quarries in geode-producing regions have good areas for collecting geodes, but access often requires significant advance planning, and you may only be able to go through club field trips. That is fine if you are a member of the club and can make plans in advance, but you are out of luck if no field trips are scheduled.

I recently had the opportunity to visit the Louisville, Kentucky, area briefly and had some time for rock collecting. Prior to my trip, I spent considerable time searching the Internet and purchased a copy of a copy of *Earth Treasures, Vol 2 The Southeastern Quadrant* by Allan W. Eckert (www.iuniverse.com, 2000). Mr. Eckert described several areas with fossils and geodes in the Louisville area. I was optimistic that I could find some productive areas with minimal effort, as opposed to my usual trips to barren areas with maximum effort.

Based on the information in *Earth Treasures* and what I had obtained from the Internet, I decided to head to southern Jefferson County near the border

with Bullitt County. This area reportedly had some geode and fossil localities. The geologic map of Kentucky, available through the Kentucky Geological Survey (KGS) Web site, www.uky.edu/KGS/home.htm, indicates that much of this area is underlain by Mississippian-age sedimentary rocks. Unfortunately, it does not get much more specific than describing them as limestones, shales and sandstones.

The KGS also had an interactive map to determine the individual units, but it was color-coded and I could not match the colors in a way that would make stratigraphic sense. I finally conceded that I would not be able to get formation-specific information, but this did not seem to be a problem. I would simply focus on finding fossils, geodes, and any other interesting minerals that could have formed in these sediments.

I began by driving south from Louisville and soon realized that I would have a problem or. I kept following the roads that paralleled the Ohio River. All the surrounding area was flat. Flat is not good if you are looking for outcrops. I know it sounds obvious, but it is very difficult to go rock collecting if there are not any rocks. I needed to find an area that had exposed rocks, whether they were in a road cut, a streambed, or even along a riverbank as rip-rap. At least I knew where I was. I had purchased a Delorme *Kentucky Gazetteer* and the topography showed a series of hills to the east. I soon took an exit and headed toward the hills on a four-lane highway, state Route 841.

I soon came to a huge shale outcrop on the south side of the highway. It looked promising for geodes, but had nothing except solid nodules and roadside trash. I soon turned back west and farther south, and took several side trips back into the mountains in a futile search for outcrops or streambeds with rocks. I had never seen a place where rocks were so hard to find.

Earth Treasures also suggested that the Ohio River near Louisville would be good for fossils, so I reasoned that the Ohio River to the south might also be good. Near the northern end of Bullitt County, I found a riverside park where I could pull over and walk to the river. I was confident that I could find some interesting rocks here, as rivers often carry rocks from other areas. Instead, all I got was a very unpleasant walk in the mud along the river. I found several promising slabs of shaley limestones and sandstones, but breaking them open only revealed solid rock with no fossils or crystals to speak of.

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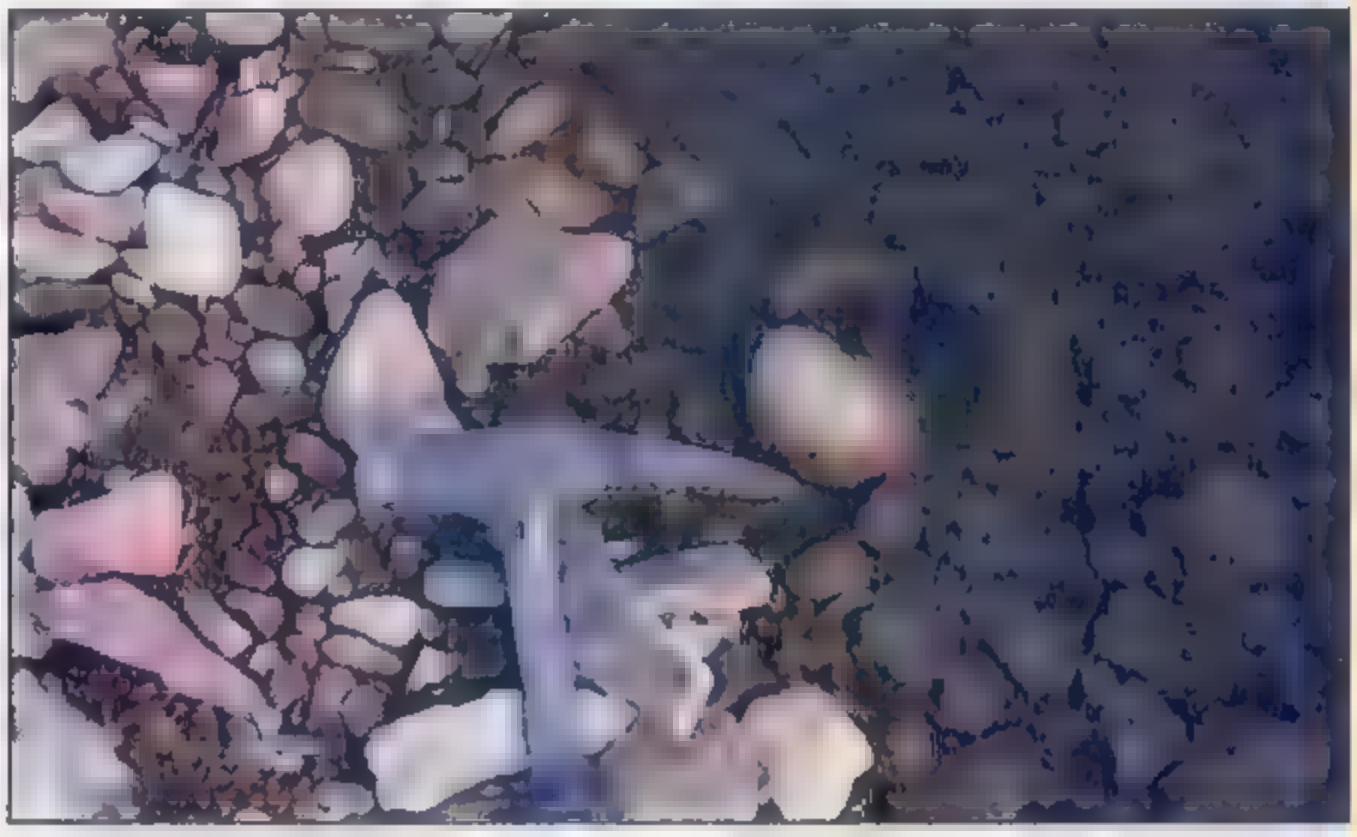
Large fossil crinoid stems can also be found along Knob Creek.

Terminated quartz crystals, as well as some doubly terminated crystals, are sometimes found within the geodes.



The potato geodes are easy to spot as they are white and have a bumpy texture.

Kentucky Potato Geodes *from page 49*

I was about to call an end to my collecting trip. So far, I had absolutely nothing to show for my efforts except a pair of mud-caked boots and a considerable gasoline bill. I began to seriously question the directions to the area given in *Earth Treasures*, although the author gave a caveat in the introduction that the directions may be vague. Although I have found the *Earth Treasures* books (the series also covers the rest of the continental United States) useful for getting pointed in the right direction, I had struck out at each of the locations in the Louisville area. However, I still thought I could find an area with fossils and geodes if I could just find a place with outcrops or loose rocks.

I decided to give it one more shot and headed east over the mountains again on state Route 44 to see if I could find any interesting road cuts for collecting. I had an Internet source (www.falsoft.necohio.org/collecting.html) that indicated that a road cut at Brooks Hill could likely produce some fossils, so I decided to give this a try. Brooks Hill was marked on my *Gazetteer*, so at least I knew where it was.

I took state Route 44 and turned left onto state Route 1526 to get to Brooks Hill. The highway soon forked, and to stay on state Route 1526 I turned to the right. Almost immediately, I drove over a small creek. This was Knob Creek, and I was surprised by the huge number of rocks that lined the creek banks. Other creeks I had seen in Kentucky had soft banks or were way too deep to adequately explore. I was especially pleased when I saw that there was a place to pull over, and there were no any "No Trespassing" signs along the creek. At a minimum, this would give me an idea of what types of rocks were in the area, and I thought I might at least find some interesting fossils or agates.

I walked along the creek and noticed that some of the banks were quite steep and of unconsolidated sediments. While the creek was generally shallow, there were some holes that looked about 4 or 5 feet deep. It looked like a good fishing creek, but I did not see any fish.

I soon noticed a very unusual rock. It was white and bumpy and appeared to be white quartz. I smashed it open and was surprised to find that it had a small open space with terminated quartz crystals in it. It was a geode, and I had never seen anything like it before.

I soon found that the geodes were quite common in the stream, on the loose rocks in the banks, and in the loosely consolidated soft cliffs along the stream. They were easy to spot as they were white, bumpy, and generally 2 to 6 inches wide. Some of them were elongated, like a large potato, and some of the white ones actually looked like a helping of white mashed potatoes. Some were a light rose color and their interior crystals had some minor light-red iron staining.

As in most geode places, not every geodelike rock was a geode. I found that about 50 percent of them were solid quartz, and of the remaining 50 percent with interior crystals, only about half would be considered good geodes. The interior features ranged from terminated quartz points to rounded, botryoidal masses of cryptocrystalline quartz with some minor banding that gave some of the pieces an agatelike appearance. The geodes were entirely quartz with some occasional hematite or limonite staining. I did not find any geodes with calcite or metallic minerals such as pyrite. I suspect they formed as nodules in the Mississippian sediments of the area and were washed down the stream as the rocks were eroded. This indicated that they were subjected to intense grinding and contact with other rocks as they made it down the stream, and only the toughest geodes could make the trip intact.

The geodes are often the size and shape of a bumpy potato.

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Potato Geodes *from page 50*

I discovered the easiest way to find the geodes was to simply walk the banks and look for potential pieces. I did not have a bucket, but I had a backpack for carrying them. I would be limited to what I could take on the plane, so I had to be selective. I know it is best to saw geodes apart, but I had a lot more fun breaking pieces open and seeing which ones were actual geodes. Generally, if they broke quickly they had some internal crystals, and many of them were quite hard to open. A hammer is necessary if you want to break them open; they are too hard to break apart using other rocks in the creek. In addition, the rocks with crystal-filled voids are hard to distinguish on the basis of density alone.

I also found some attractive crinoid pieces in this spot. These were interesting, as they were quite large, in some cases nearly 4 inch in diameter. I found these loose in the stream and I am sure there are many others to be found.

I initially focused on the north side of Knob Creek, then walked along the banks south of the state Route 1526 bridge. I tried to keep my feet dry at first, but it soon became apparent that the only way to get around was to get into the creek, as some of the paths were only accessible on one side. I found a considerable number of potato geodes on the southern side of the bridge as well.

I soon saw a couple of people in the woods and realized they were coming to the creek. I was uncertain of the land status, so I hoped that I was not about to have a problem. Fortunately, they were just a father and son out fishing, and they were trying to catch some bass in the deeper parts of the stream. They were very friendly, and I showed them a couple of the better geodes I had found. Not surprisingly, they showed absolutely no interest in them. I believe I was the first rock collector they had encountered on this creek.

I had collected several pieces for cracking open later, and as I expected several of them were solid masses of quartz. I had to hit one of the pieces repeatedly with a large hammer. With the last giant whack, it opened to reveal a brilliant interior of sparkling quartz with a large terminated quartz crystal at its center. The crystals were clear, but their appearance reminded me of Herkimer diamonds and leaded glass. They were extremely bright and

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Potato Geodes *from page 52*

seemed to sparkle. This particular piece was light gray, about fist size, and had a very bumpy exterior, so this could be a guide to which are the most likely pieces with sparkling quartz crystals.

This is an easily accessed area if you are in the Louisville area. You can either approach it from the Ohio River side via U.S. Highway 31W-60 or from Interstate 65, which is the main highway that leads south from Louisville. From U.S. Highway 31W-60, take state Route 44 east to state Route 1526 and head northeast. This road is also known as Knob Creek Road. It soon intersects with state Route 2672, which continues on as Knob Creek Road. Stay on state Route 1526, which will require turning to the right onto a section known as Brooks Road. You will then cross Knob Creek. The parking area is just east of the bridge on the south side of the road. If you are coming from Interstate 65, take Exit 21 to the west and cross state Route 1020 to state Route 1526. Stay on state Route 1526 until you cross Knob Creek and park at the area just east of Knob Creek and south of the road.

This is an easy area to reach, and it only requires a two-wheel-drive vehicle. You will not need to leave any of the main roads. The parking area is at 38.0427°N, 85.7933°W, and the area on the north side of bridge where I started to find geodes is at 38.0432°N, 85.7931°W. The area is on the USGS Valley Station, KY 7.5-minute topographic quadrangle. I would recommend getting a copy of the *Kentucky Gazetteer* or driving around this area if you can, but a Kentucky highway map should be adequate if this is all you have.

This is a collecting spot that should be good for bringing your kids, spouse, or anyone else who may have a short attention span. The potato geodes are easy to find and with luck you will find some good specimens fairly quickly. You will also likely find some unusually large crinoid stem fragments. A hammer is definitely recommended if you want to open your potential geodes, and I would also bring a bucket or large backpack, as you will quickly become overloaded with rocks. The area is constantly refilled by periodic stream flooding and weathering of the bedrock, so this area should not be a victim of overcollecting. This site will continue to produce interesting geodes for a very long time.

FIELD TRIP

Minas Basin Minerals

Nova Scotia Offers Many Collecting Opportunities

Story by Carol Lamb

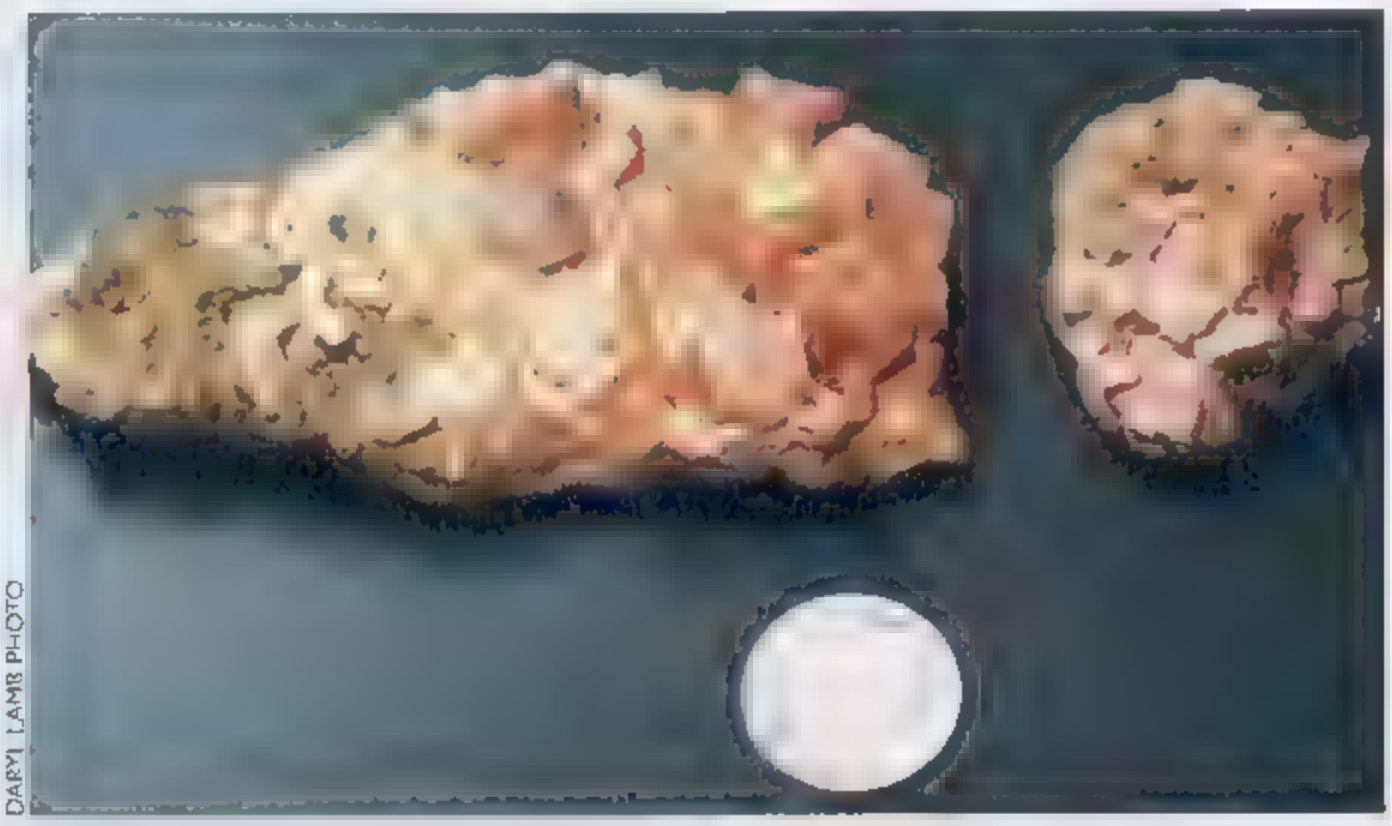
LOR JAMB PHOTO

The North Mountain Basalt that forms Partridge Island holds many zeolite treasures waiting to be found.

I gazed at the flats of stilbites and heulandites displayed for sale at the mineral show. Classic shapes and exceptional size were their hallmark. My family and I had never been really successful at collecting zeolites. An occasional microscopic crusting of stilbite on a pegmatite and some natrolite were about the extent of it.

Sure, we could buy the specimens coming out of India that are setting the new standard for these types of minerals, but the real fun for us has always been self collecting. In that regard, India is out of my reach. Table Mountain, Colorado, is essentially closed, and I am unsure of the status of the famous Paterson, New Jersey, quarries.

My home state of North Carolina also has a decided lack of basaltic traps. There is, however, a locale that still produces a selection of collectible specimens of various zeolites, the Canadian maritime province of Nova Scotia. The basalts outlining the Minas Basin along the Bay of Fundy coastline continue to offer collecting opportunities as the Fundy tides eat away at them, constantly liberating new material. Though it was an ambitious drive, we headed for "New Scotland" in June 2006.



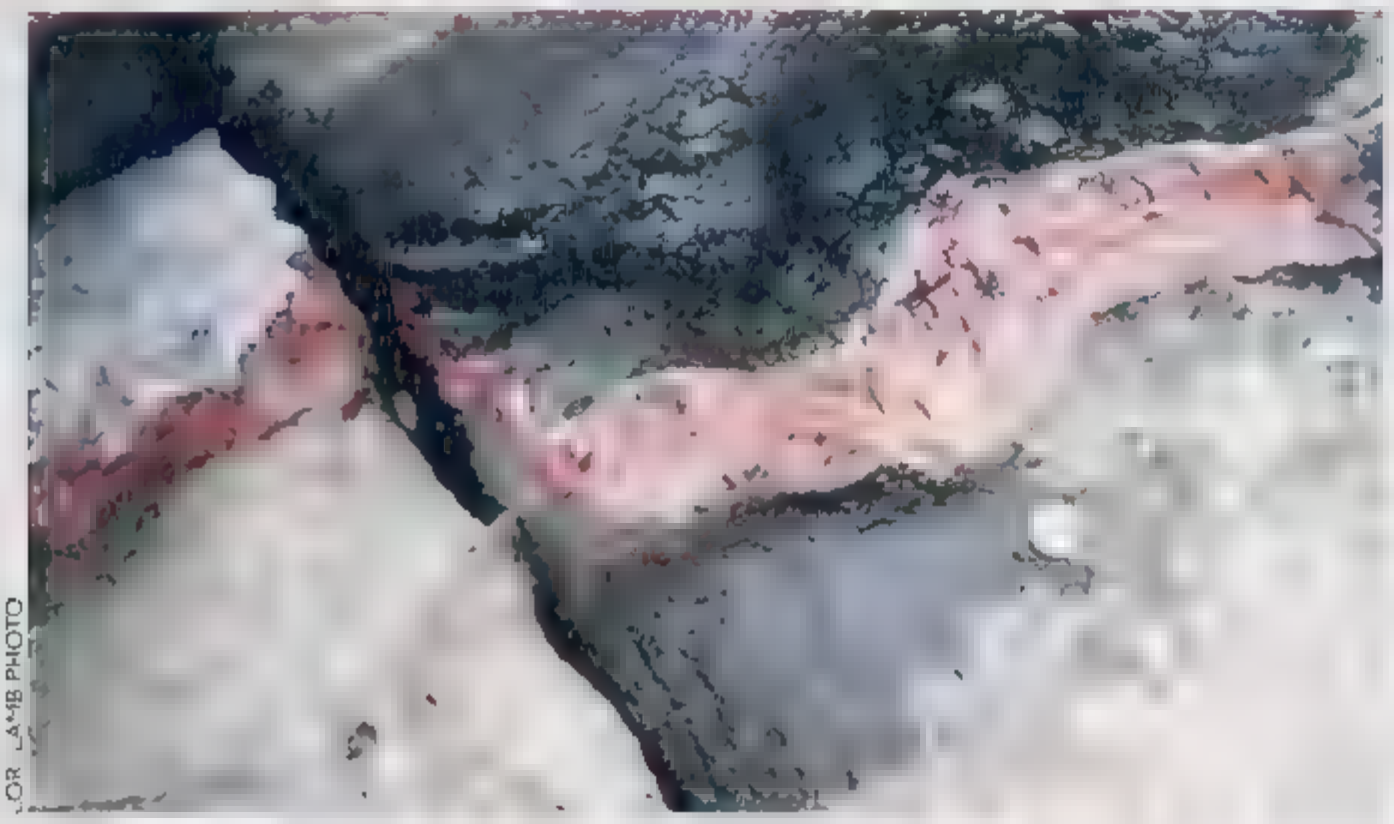
DARYL LAMB PHOTO

The reddish chabazite found near Parrsboro was originally referred to as acadialite.

Zeolites are a group of related minerals that are broadly classified as silicates. They frequently occur in vesicles and seams in basalts, the product of late mineral formation as mineral rich fluids collected in and percolated through the characteristically porous host rock. They can also be found though usually less spectacularly as crusts on some pegmatites.

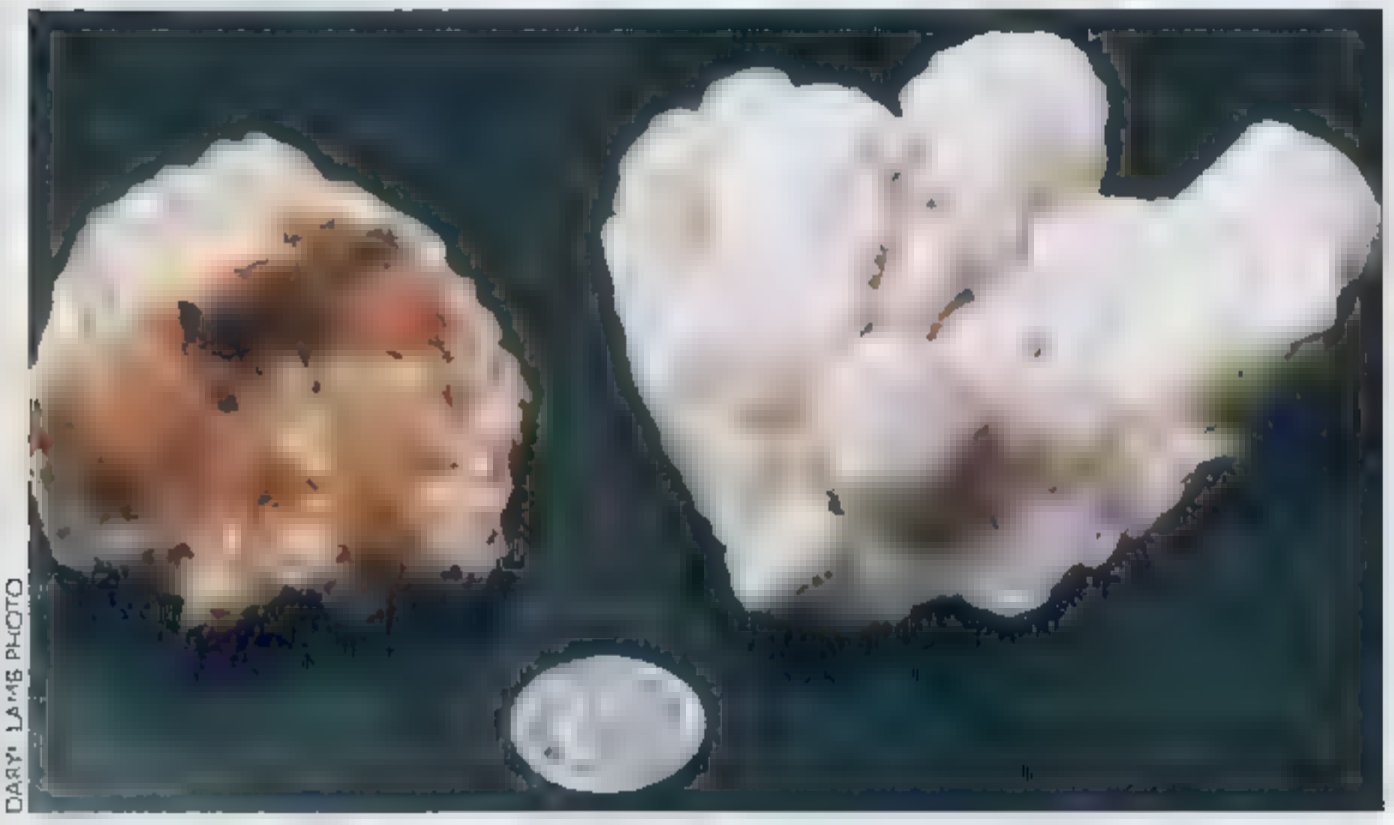
Although there are more than 40 naturally occurring zeolites, the most familiar ones include stilbite, chabazite, heulandite, analcime and natrolite. Chemically, zeolites are similar in their overall sodium (Na), calcium (Ca), and/or potassium (K) tetrahedral framework, having a rather "open" structure. They give up H_2O readily when heated, yet the atomic lattice does not collapse.

The Swedish mineralogist Axel Fredrik Cronstedt observed that the



DARYL LAMB PHOTO

This nice vein of mahogany jasper cut a seam across the basalt at Cape Split



DARYL LAMB PHOTO

The color of the stilbite varies across locations along the Minas Basin from yellow-orange to snow-white.

DARYL LAMB PHOTO

Stilbite with a definite fanning pattern is abundant at Partridge Island.

minerals seemed to dance when boiled, so he coined the term "zeolite" to describe them. The term is derived from the Greek "zein," meaning "to boil," and "lithos," meaning "stone."

From a commercial perspective, the loose atomic structure of zeolites allows them to trade certain positive ions, and this quality makes them attractive as molecular sieves. They are used in water purification and softening, as well as in the agricultural, medical and petroleum industries. Large demand is now satisfied primarily by synthetically produced zeolites. That leaves the natural ones for collectors.

Nova Scotia has been known as a zeolite locale for over 100 years. The geology of Nova Scotia that lends itself to these zeolites was born in the early Triassic period. During the Triassic, Nova Scotia was still a part of Pangea. As the great landmass began shifting, on its way to eventually breaking apart, rift valley systems formed along tension regions. The thinning of the crust in these rift valleys allowed fault zones to form, including the Cobequid-Chedabucto Fault. In the vicinity of the fault, the ancient Fundy Basin formed. Its location is almost identical to that of the current Bay of Fundy.

Sedimentary deposits filled this basin for quite some time. As the continents continued to move during the late Triassic and early Jurassic, magma moving through deep crustal fissures erupted at the Fundy Basin. This igneous activity is evidenced today as the North Mountain Basalt Formation, which underlies most of the current Bay of Fundy. The coveted zeolites, along with quartz, agate, amethyst and calcite, are found within this formation where it outcrops around the bay. Geological maps of the area show that the North Mountain Basalt generally outlines the Minas Basin shore from Brier Island to Cape Blomidon on the south, and from Cape D'Or to Five Islands along the north shore.

The presence of these basalts as a host for the zeolites is, however, only half of the equation that yields an ongoing supply of specimens. The world-famous Bay of Fundy tides serve as a mechanism for liberating specimens, and can be a formidable, even dangerous, force worthy of serious respect from the collector. The extreme tides are caused by a combination of factors that include the geographically funnel-shaped bay, its progressive shallowing, and the associated tidal resonance. These factors combine to amplify the tides to their famous extremes.

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Minas Basin Minerals *from page 61*

The Minas Basin is an inner arm of the greater bay, and as such it particularly benefits from these tidal extremes. Parrsboro harbor claims the highest tides on the Minas Basin arm with a difference of 54.6 feet from peak of high tide to fall of low tide, in a cycle that occurs every six hours and 13 minutes. The phenomenon is marketed as a tourist attraction at various points along the bay and inland, particularly in areas where rivers draining into the bay experience visual tidal bores and appear to reverse their flow. The Reversing Falls in Saint John, New Brunswick, as an example, is a frequently visited site for vacationers.

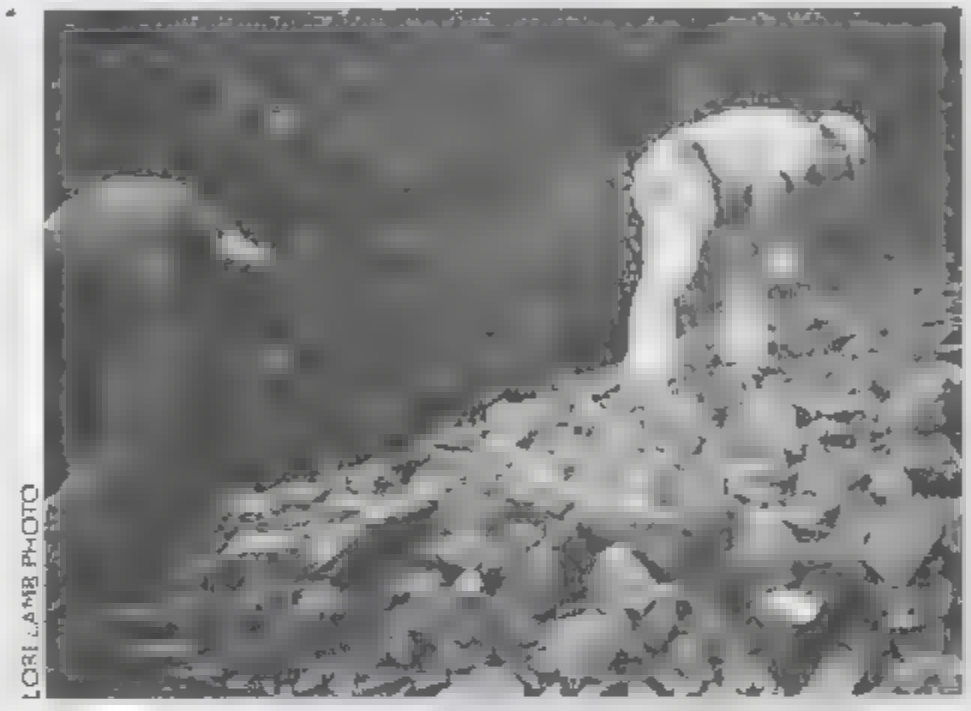
After consulting maps and other online resources to locate a centralized base, we chose Parrsboro, Nova Scotia, as our destination. The three-day drive involved an international border crossing and the loss of an hour as we entered the Atlantic time zone. I regret that we did not have time to explore and enjoy New Brunswick. One feature that piqued my interest was the road cuts along Provincial Highway 1 from Saint John to Moncton, New Brunswick. Even traveling at 65 mph, we could easily see the abundant ripple marks in the exposed sedimentary strata. I couldn't help but wonder what else might be captured there, but alas, we were on a tight schedule.

Most of Nova Scotia is surrounded by the cold waters of the northern Atlantic Ocean, connected to New Brunswick by an isthmus. Geology-based tourism, timber, and agriculture, especially strawberries and blueberries, are the primary industries in this quaint village. The town traces its inception back to 1607 when Samuel de Champlain stepped onto nearby Partridge Island. The original town was established there, but was relocated to its present location in 1784 by Admiral John Parr, Governor General of Nova Scotia, and renamed Parrsboro.

The early settlers had to interact with the indigenous tribe, the Mikmaqs. A statue of the great Mikmaq warrior-god Glooscap presides over the square at the north end of Main Street. According to native legend, Glooscap created the Fundy tides and scattered the gems now found along the shore. This seems to reflect that even the native tribes valued these minerals enough to weave them into their lore.

Parrsboro, a town of about 1,600, lies on the north shore of the Minas Basin. Main Street has a very small-town flavor; tourists are easily spotted, but welcomed. To pay homage to its most recent claim to fame, the town displays lighted, wire-framed dinosaurs on the telephone poles along the main routes. We stayed in some charming cottages just outside of town, as there are no chain motels here. Other accommodations include bed and breakfasts and camping, but none are in abundance. If you plan a trip, make arrangements well in advance.

To lay the groundwork for collecting, we visited two of the town's main attractions: the Fundy Geological Museum and the Parrsboro Rock Shop. The museum is situated on the Parrsboro harbor and tells the story of the geology and paleontology of the region. There are fine reference displays of zeolites and other minerals found around the basin, correlated with their location. This is an excellent and necessary preface into discovering where and what to collect.



LORI LAMB PHOTO

Collecting along the slide area on Partridge Island requires careful footing and a sharp eye for the small zeolite specimens.

The Fundy tides are well explained, with tide tables available, and a sitting area offers an excellent view of the harbor as it fills and drains like a giant bathtub twice a day. Additionally, there are paleontological displays of the area's carboniferous fossils and a unique display of the famous dinosaur footprints discovered by local legend Eldon George in 1984 near Wasson's Bluff.

While collecting zeolites in the region, George noted preserved trackways in some red sandstones of the cliffs. The tracks appeared to be made by a small three-toed creature roughly the size of a robin. This find, now heralded as some of the world's smallest dinosaur footprints, prefaced an even greater find. In 1986, Dr. Paul Olsen of Columbia University and Neil Shubin of Harvard University announced their substantial find of Triassic-Jurassic boundary fossils. The discovery eventually produced more than 100,000 pieces of fossil bone from small dinosaurs and crocodiles.

As a result of these important discoveries, the site is now designated the Parrsboro Fossil Cliffs and is protected under the Special Places Protection Act. This makes the cliffs a "hammer-free zone" and restricts collecting and climbing in the area, though one can still visit this area and take in its geological significance.

The second stop in our preparation phase was just south of town at the Parrsboro Rock Shop, owned by Eldon George and his son. Tables inside and outside the shop were covered with specimens, many self-collected, that represent the best the Minas Basin has to offer. Eldon was on hand and was most helpful in giving us advice on where and how to have the best collecting experience. Though not as active as he used to be, Eldon will still occasionally host collecting trips to local sites, especially in August, when Parrsboro is host to the annual Nova Scotia Gem & Mineral Show.

Though specimen collecting is part of the economy in Parrsboro, we could not find any collecting guidebooks specific to the area for sale. The museum does offer two general references that are useful: "Nova Scotia Rock: Explore Our Geology," a pamphlet by the Atlantic Geoscience Society (AGS), and the "Nova Scotia Geological Highway Map," also by AGS and the best reference of the two.

After wetting our collecting appetites, we returned to our cottage and collected our gear. The slow drizzle and fog that greeted us that morning had lifted, and we were finally ready for our inaugural trip to the shoreline. Successful and safe collecting along the bay requires careful consideration of the tides. Since the tides reach their extremes every six hours, the best strategy is to reach your collecting site about 30 minutes to an hour after the high-tide peak. This gives you a full five hours to collect as the tide recedes without having to watch the water. Even then, at many locations there is an additional two- to three-hour window of reasonable safety as the tide begins to rise. This is not a hard-and-fast rule; once the tides start rising, it is best to consider packing up.

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Minas Basin Minerals *from page 62*

Since it was midway through the receding tide we were limited on time and decided to collect close by. The Parrsboro shoreline area encompasses five documented sites, from southwest to northeast, and their yield varies. Cape Sharp is known to produce agate, quartz and amethyst. West Bay hosts carboniferous fossils and petrified wood. Partridge Island yields zeolites. Cars Head has gypsum, dolomite, pyrite and calcite, and Wassons Bluff/Two Islands is famous for zeolites. Based on Hilton George's recommendation, we headed to Partridge Island.

Partridge Island was indeed once an island, but in 1869 a ferocious storm known as the Saxby Gale created a land bridge sandbar connecting the island to the mainland. The sandbar has been expanded over the years and the island can now be accessed via an easy passable pebble causeway. Just off the parking area there is a picnic table and hiking trails that lead to viewing spots atop the island. The island is entirely North Mountain Basalt, and the beach is really medium to large boulders of basalt, some covered with kelp and very slippery.

We learned quickly that the desirable specimens were not far out on the beach, where water had rolled them beyond recognition, but up close next to the basaltic walls. We carefully picked our way around the island, following the walls. It wasn't long before small pieces of stilbite began to appear, easily distinguishable against the homogeneous black basalt. Their source, though, was several sheer feet up, and not accessible.

A bit farther around we came upon a substantial slide area that afforded better opportunities. Here, Mother Nature had done much of the work for us, breaking the host rock and freeing the zeolites. As we worked our way from the base of the large slide we quickly found nice pieces of brown stilbite in the classic 'wheatsheaf' habit. While they were slightly weathered and not *in situ*, they were still very nice and rather large at 3 to 4 centimeters, with pronounced fanning.

While my husband and son scratched carefully among the rubble, I found haven among some large boulders and began wrapping the fragile finds. It struck me that this very spot had been totally submerged a few hours earlier, and would be again.

As I worked, a glimpse of purple caught my eye, and I was thrilled to find a nice piece of amethyst crystal wedged beneath my feet. There were a few other pieces of nice quartz agate in the same vicinity, one exceptional piece was covered with gray patterns similar to Mexican crazy lace agate. After a very quickly passing hour, the fog abruptly rolled back in and the rain returned, ending our collecting for the day. This spot was, however, going to merit a return visit the next day.

It seemed fitting that the first zeolite we found was stilbite. Stilbite is ubiquitous around the basin, so much so that on Nov. 5, 1999 it was officially declared Nova Scotia's provincial mineral. The stilbite occurs in both cavities and seams in the basalts. While they primarily occur in the classic 'sheaf' habit, color (grades of brown to golden yellow and orange, and even creamy white) and size tend to vary across locations. The Fundy museum has an excellent display of stilbites from the region.

The weather improved on our second day, and we returned to Partridge Island just after the peak of high tide to allow maximum safe collecting time. Another session at the slide area produced more stilbite, as well as some reddish chabazite in small crystals (3 to 6 millimeters). A few were accented with small calcite scalehedrons, as is common in this locale.

My son's keen eye also picked out a single transparent analcime crystal perched on a chabazite pedestal. Analcimes along the basin tend to be transparent when first exposed, but turn opaque white after prolonged exposure. This little fellow must have been protected in the debris of the slide.

We proceeded farther around the walls and came to an area with what had been a large pocket of small, bright-yellow stilbites on calcite rhombohedrons. There was little left in the opening, so I could only imagine the specimens that some lucky collector had removed. The work seemed pretty fresh, and we decided to try our hand at what was left. We were able to extract a few nice pieces of very small but extremely colorful stilbite overgrowing a matrix of calcite.

As my son reached to retrieve a piece that had fallen amidst the rocks, he realized there were more loose pieces down under our feet, probably pieces that had shattered from the pocket during the original extraction attempts. We decided to scavenge and see what might have flown out of the vug or been dropped and left behind. This turned out to be an unexpectedly good move. As we removed the large chunks of basalt with only a few mashed fingers, we discovered several surprisingly nice stilbites that had 'gotten away.' Then, as we cleared the area at the base of the wall, we saw the opening of another vug.

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The constant exposure to seeping water had weathered the host basalt, and we were able to retrieve pieces from this area almost exclusively by hand, helping to preserve them. Though small, they were a rich golden yellow and they made exceptional thumbnails. And the fun we had finding them made them all the more gratifying.

On our third day, we decided to explore the areas west of Parrsboro and along the Chignecto Bay. Following the Fundyshore Ecotour signs, we took this scenic loop a bit inland to Springhill, famous for coal mining and the Anne Murray Center there, then to the Joggins Fossil Cliffs back along the shore. These cliffs are renowned for their preserved remains of multiple carboniferous-period fossil tree stumps. The auto tour then took us to the lighthouse complex at Cape D'Or, situated at the entrance to the Minas Channel. The shoreline here is very rugged and precipitous, with essentially no "beach." Still, the North Mountain Basalts exposures here have been collected by the intrepid. The area was once an active copper mine.

Mining did not actually occur until the very late 1800s, and was short lived. In 1897, the Colonial Copper Co. worked the area, sinking three shafts and sending ore to a mill built nearby at Horseshoe Cove. But the actual amount is unknown and by 1905 the mine was no longer producing. Copper can still be found encased in zeolite seams in the basaltic joints around the Cape, but the arborescent copper is extremely small and requires detailed extraction with a needle under a scope, something that well exceeds my patience quota.

Along with the standard array of zeolites, the Cape has also produced some apple-green apophyllite. The complex at the lighthouse is below the road, and one actually hikes down to the point. There is a charming restaurant here where dining guests can watch the tides ebb and flow over the rugged cliffs. We spent a little time scoping out the cliffs, but opted out of this adventure. After enjoying a drink at the restaurant, we headed back up the steep drive to the parking areas above.

Along the edge of the driveway, the basalt crops out again, and my son noticed what appeared to be a piece of weathered analcime lying in the draining ditch. Then, at about eye level, we found its source, a weathered seam of analcime crystals, already opaque from exposure. The specimens came out with minimum effort, essentially just by reaching and pulling, thanks to the effects of elemental exposure. Up much higher, out of reasonable reach, was a vug of white stilbites, a little stained by the falling overburden from above. We found a few small, loose pieces at our feet and settled for them. At least this site was not a collecting bust, and the scenery was exceptional, worth a visit in its own right.

The next morning, we planned to visit the other side of the Minas Basin to collect different zeolites. This was a classic example of driving around one's elbow to get to the thumb. There is no bridge or ferry across the channel, and even though one can easily see across to the other side, one must drive the perimeter to reach the opposite shore. Interestingly, this was not always the case. From the early 1840s right on to the early 1960s, there was a ferry from Parrsboro across to Windsor, a trip of less than 20 miles. For years, this was the primary route across the basin. Then in the 1960s, the TransCanadian Highway bypassed Parrsboro, cutting a more inland route to Halifax. With the substantial decline in traffic and demand, the ferry discontinued services. Thus, we headed out from Parrsboro on the four-hour drive to Cape Split.

The trip was scenic, paralleling the coastal region along Cobequid Bay, traversing timber country, passing the large gypsum mines at Windsor, and then climbing the ridge that overlooks the agricultural bounty of the Annapolis Valley. The journey ended as Highway 358 dissolved into a parking area at the tip of Cape Split, from which hiking trails lead in several directions to access Cape Blomidon and Amethyst Bay.

The tide was just beginning to recede, so we worked our way down the cliffs at Cape Split. Here the basalt is not particularly vesicular, but is instead cut by several decent-sized seams of agate and jasper. Our best take home from here was some exceptional, deep maroon jasper, smooth and excellent for future cabbing, as the seams were around 6 to 10 centimeters in width. There was also one area of superb mustard-colored jasper that had been thoroughly worked. No face or edge was available by which to leverage a piece, and the overhang just above it begged the question of safety, so we left it behind. Several other hikers were in the area, seemingly just enjoying the beauty of the bay. We, however, wanted to visit as many spots as possible, so we moved on to our next target.

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Minas Basin Minerals *from page 66*

Following the local roads referenced on the Nova Scotia map, we headed southwest and were able to again access the beach at Ross Creek. This was not a locale referenced anywhere, but a local woman at the museum had mentioned that she and her husband came here often and were always successful. We obtained permission to park from a local homeowner, and headed out onto the beach.

The tide was already down quite a ways, and we immediately began to notice that the beach was covered with a lot of basalt pockmarked with pink and orange vugs. They were pretty rolled, so it was difficult to distinguish the mineral type. We proceeded down the beach surveying the basalt walls. Here indeed was the answer.

The basalt here was extremely vesicular, in contrast to Cape Split just a few miles away. The sheer cliff faces were covered with fist-size vugs lined primarily with heulandite. On this side of the bay, heulandite is common and ranges from colorless to white, pink, orange and even red. The crystals here are not all that large, and display a chisel-tip shape instead of the classic coffin shape. We were able to very easily extract several nice specimens here, most of them pink-orange. Though the spot is also known for amethyst, we did not find any here, though I did locate one outcrop of agate.

Continuing southwest, we next accessed at Hall's Harbor, an active inlet known for its seafood restaurants situated on the water's edge. The basalt was again punctuated with heulandite, but the vesicles were also filled with a green mineral that frequently coated the zeolites. This green coating is identified as celadonite, a micaceous mineral named after the French "celadon," meaning "sea green." The mineral coating reminded me of a copper mineral, but there is no copper in the complex chemical formula listed in Fleischer's *Glossary of Mineral Species*. It is also not to be confused with calcite, a lead copper sulfate, even though the spelling is similar.

Other specimens found at Hall's Harbor include sprays of natrolite, some coating the heulandite, others within the celadonite-lined cavities. We found a few nice specimens, but they were small compared to historic finds in the area.

Opportunities to collect various zeolites continue down the coastline wherever one can gain access to the beach and the basaltic walls. Harbourville is a favorite location among local mineral clubs and is known for the snow white stilbite found there in larger specimens than elsewhere around the bay. At Morden, Henry How first found the small, white, botryoidal masses now known as mordenite, identified in 1863. To truly maximize collecting opportunities at these locales, one should spend at least three days on this side of the bay, a strategy we overlooked, but one I now recommend. There are numerous towns with charming accommodations in the area.

The fifth and final day of our trip opened with rain, so we did laundry and repacked mineral specimens for the trip home. In the late afternoon, a break in the clouds afforded one more collecting opportunity, so we headed to the signature location at Wassan's Bluff. Once the crown jewel of zeolite collecting here, Wassan's Bluff is now designated a Special Place by provincial law. This has rendered the location a hammer-free zone, with severely limited collecting. Depending on the source, it appears that one can only collect one or two pieces of loose material (mineral only) found on the beach. Climbing on the outcrops is not allowed.

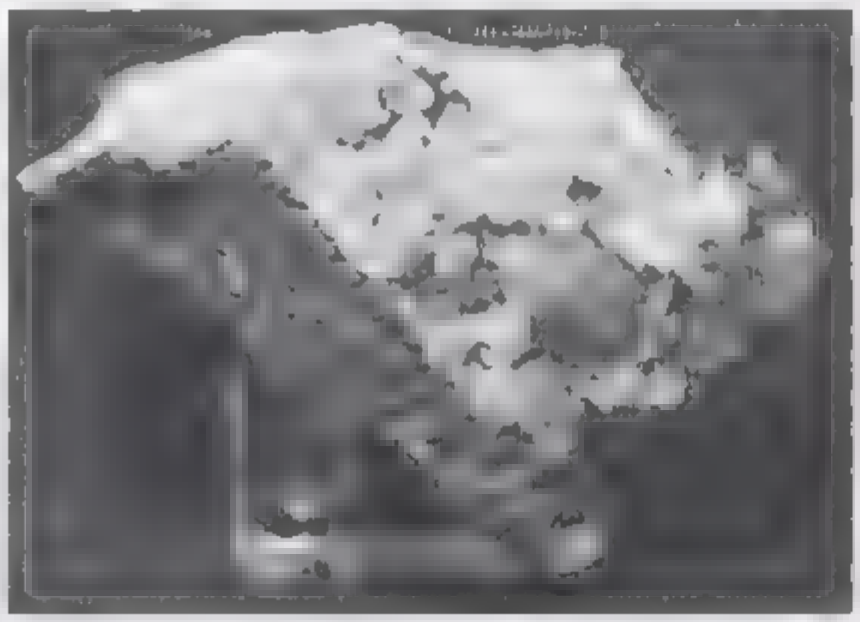
Since the car was already full, it was just as well, but we decided to walk along and take in the geology. The exposures include zones of basalts (home to the zeolites), breccias, and sandstones (home to the fossils). Early references to the chabazite that is so prolific here date back to 1828. In 1834, the term "acadialite" was coined to describe the deep-red, often large chabazite found there. This term, though still used locally, is no longer recognized nomenclature. The chabazite ranges in color from the famous deep red to orange, pink and even colorless. Color may even grade within a pocket, and penetration twinning is very common.

I recalled some stellar specimens from these cliffs back at the museum. Today, the chabazite is still prolific, though specimens are apparently much smaller than historical finds. We came upon an area where the basalt was covered with hundreds of vugs containing bright-orange chabazite. Unfortunately, the effects of weathering upon the loose samples were extensive, with edges eroded either by frost damage or recurrent water motion. It was evident from freshly broken rocks that collecting had been done recently, in spite of the rules.

Farther along, we came to a small, cave-like arch where we spotted, several feet overhead, a very large, nicely formed analcime crystal in a basalt vesicle. It was probably at least the size of a quarter. It gave us some perspective on how beautiful the specimens here had been.

By now, the rain was picking back up, so we truncated our walk and returned to our vehicle. One additional feature of the area is the view of Two Islands directly across from the bluff out in the basin. Two Islands is also famous for zeolites, but is accessible only by boat with a guide. It is known for specimens of gmelinite, a lesser-known zeolite similar to and often confused with chabazite.

Geologically and mineralogically, Nova Scotia has much to offer. We merely scratched the surface. The province has a rich mining history including tin mining at Lost Kemptville, barite mining at Magnet Cove, coal mining at Cape Breton, gold mining, and the still-producing gypsum mines at Milford and Windsor. Nova Scotia is the type locality for several minerals, including the aforementioned mordenite, howlite, named after Nova Scotia mineralogist Henry How, and the lesser known minerals meauslanite, aphowrite and moorhouseite. For the paleontologist, there are opportunities to study plant and dinosaur fossils from various ages including Carboniferous, Triassic, and Jurassic. The Minas Basin is just a starting point, a collector-friendly introduction to an area that is well worth the acquaintance, and one that should be revisited many times.



DARYL LAMB PHOTO

This golden stilbite on calcite was removed from a weathered pocket on Partridge Island.

For More Information

Fundy Geological Museum, PO Box 640, Parrsboro, NS B0M 1S0, Canada, (902) 254-3814, (866) 856 DINO, http://museum.gov.ns.ca/fgm/

Parrsboro Rock & Mineral Shop, 349 Whitehall Rd., Parrsboro, NS, B0M 1S0 Canada, (902) 254-2981

Dinatours (mineral and fossil tours), 87 Two Island Rd., Parrsboro, NS B0M 1S0, Canada, (902) 254-3700

FIELD TRIP

Treasure State Adventures

Part 1: Collecting Yellowstone Agates

Story and Photos by Kenneth H. Rohn

I was recently invited on a trip as a guest of Travel Montana and Donnie Sexton, travel manager for the state. I investigated and collected gemstones at various Montana sites where the general public is welcome. I also got to see some of Montana's unusual geological and historical sites.

Rockhounding is a recognized outdoor activity in Montana, and the Yellowstone River and its environs in Custer Country hold a vast bounty of treasure just waiting for us to discover. Custer Country is that splendid area of vacation land in the southeast corner of Montana.

My adventures began on my way to meet Donnie. It was a very hot summer day when I drove west from my home in Minnesota. I was thankful that I had ordered air conditioning in my new pickup. It certainly is a welcome accessory, especially when the temperature is hovering at 90 degrees in the shade.

Sections of U.S. Highway 2 (my main route west) in North Dakota are four-lane freeway, but quite a bit of the route is still two-lane. In a very long section, a new road is being built alongside the old one. This will soon be another section of freeway in the western part of the state.

As you may know from reading of my adventures in *Rock & Gem*, I've spent many happy hours collecting Montana moss agates at sites along the Yellowstone River. There are several public fishing access points on state Route 16 and Interstate 94, from Sidney all the way west as far as Billings. Much of the land adjacent to the river is private property, but there are those access points that make it possible for us rockhounds to collect without trespassing.

I would venture to say that in all probability, only a small portion of this stretch of the Yellowstone and the terraces above it have ever been fully explored. This is a very large area, approximately 250 miles long and several miles wide in a few places. The possibility of finding gemstones a great distance away from the river in the ancient terraces is excellent. On one trip several years ago, I found jasper and beautiful moss agate several miles north of Terry in the washes of a small creek alongside a private ranch road.

Due to the sometimes violent action of the Yellowstone, especially during spring runoff, the majority of stones we find have been water worn and rounded off, and actually resemble potatoes. Although I have yet to find a large agate that is over 5 inches in diameter, they have been found by several diligent collectors. I saw a beautiful specimen in the rock shop at Fairview, North Dakota. It's about the size of a small loaf of bread and just about the same shape. The dendritic inclusions of manganese oxide are very pronounced in this wonderful, translucent stone. Some specimens that are 10 inches in diameter have been found in gravel bars of the Yellowstone.

There are several public fishing access points along the river where we can park our vehicles and collect. Of course, not all of these access points have gravel bars, but the ones that do are fantastic.

The rules for collecting vary a bit with each government department in Montana, but basically they are similar. The National Forest Service advises us to collect a reasonable amount of petrified wood and agates. One national forest site I visited only allows the collecting of one piece of petrified wood the size of one's fist and a permit is mandatory (see "The Petrified Forest of Gallatin," December 2000 *Rock & Gem*).

As of this writing, Bureau of Land Management (BLM) regulations allow the collecting of 25 pounds of agate and/or petrified wood, plus one piece, per day and 250 pounds per year for our own personal use, not for sale. This is a very generous amount. If someone wishes to collect for commercial purposes, a special permit is required.

Upon arriving in Montana via state Route 200 and state Route 16 from the northeast, I decided to visit the public fishing access at Crane. As a matter of fact, I couldn't resist it. I was eager to see that fabulous gravel bar again after an absence of one year.

What comes to rest on the bars along the Yellowstone—and how much of it—is dictated by the depth of winter snow in the state, plus the quantity of spring rain that falls, adding to the runoff. The power of water plays a big part in bringing stones to rest on the bars.

When I walked down to the river, I wasn't disappointed. The only detriment of my collecting adventure was the heat of that day. I had never collected here when it was this hot before. But that didn't stop me. I put a bottle of iced tea in my rock pouch, put on a cap, and set out.

The bar hadn't noticeably changed since my last visit. In some areas, the rocks were covered with a layer of fine sand. I had not seen much of this before, and I suspect that there must have been several days of high wind along this stretch of river prior to my visit. Still, a good number of rocks were exposed and clean enough for identification.

A variety of colorful gemstones can be found on the Yellowstone River gravel bar.

I stopped to admire the river and the surroundings. The gravel bars on both sides, going downstream, extend for at least a quarter mile until the river makes a bend. From there, the one on the highway side continues as far as the eye can see and is heaped with cobbles and rocks of all sizes and shapes. I have never walked the entire distance of the bar on the highway side of the river. Some day, I'll find the time to do just that.

Human nature being as it is, we tend to seek the easy way. Therefore, the areas around the parking places will often be the most picked over. At the Crane access, I walked for quite a way before I found my first gem-quality agate. Of course, there are numerous specimens of chalcedony in the form of agates and agatized wood, plus jasper and the more drab petrified wood, almost everywhere one looks, but the quality stones are the first to go near the road.

As I approached the bend in the river, I began to find the most interesting agatized wood pieces. Some of them are so finely polished by nature that it would be a waste of time to try to improve upon it. The banding in these stones is phenomenal. The growth rings alternate from brown to creamy white in all those that I found. Some bands are crowded so tightly together that it will take magnification to see them. This made me wonder whether all these fragments came from the same section of an ancient tree and broke up during the trip downstream. It's a possibility.

The narrow, tightly banded growth rings mean that at the time these trees were alive, some 30 million to 50 million years ago, growing conditions were not good. Tightly spaced rings suggest the trees may have suffered from a scarcity of nutrients. Judging by the appearance of the specimens I found, the trees may be some extinct species of soft wood such as pine or fir.

Several of the pieces of agatized wood that I picked up in that area are no larger than one's thumbnail and well rounded. I'll enjoy making brooches with these stones. All I need is a few bezel crowns in either gold or silver and some quality jeweler's glue.

continued on next page

A beautiful specimen of agatized wood resembles contemporary oak in many respects.

At the bend in the river, the bar is at least two city blocks wide at one point. I noticed that the rocks close to the water were covered with a thin layer of mud that would make it hard to identify them, so I spent my time searching along the middle and outer edge of the bar, where the rocks were exceptionally clean.

To back up my earlier statement, the quality and quantity of the stones improved as I walked farther downstream from the parking area. It wasn't long before I was forced to become extremely selective. I kept only the very best-looking stones, because my pouch was beginning to fill up.

I got a thrill while slowly examining the myriad stones before me. I was walking into the sunlight when I noticed the translucent tip of a stone a few feet ahead of me. The exposed area was lumpy and covered with dirt, but it glowed a translucent light gray, and I knew it had to be an agate. I wasn't particularly impressed until I washed it in the river. Then I saw that I was holding one of the most magnificent examples of Montana's state gemstone. It's a creamy gray color, with thin, wavy dendritic inclusions running through it.

Several of the stones that I decided to keep are such a dark brown they appear almost black. I picked up one nodule the size of an orange and just as symmetrical. It's one of the dark stones, and I'm anxious to see how it will look when it's sliced open. It should make some very impressive wind chimes.

By this time, my walk had taken me out of sight of my truck. The day seemed even hotter now, and my iced tea was almost gone. My rock pouch hung heavily on my hip, and I still had the return trip to make, but I was having a ball.

The only good method for hunting agates that I know of is to walk into the sun, or at least use the sun as a guide for identifying them. If the stones are dirty, that's another problem, and only careful examination can reveal their true identity.

Throughout the years, I've searched in a zigzag pattern from the outer edge of the gravel bar to the water. I've walked in parallel lines spaced about 6 feet or so apart and, perhaps, 100 yards long. I have searched in ever-widening circles on the bars. Quite often, I just wander about with my attention concentrated on the ground ahead of me. Everything seems to work after a fashion.

I found this beautiful moss agate at the Intake Fishing Access on the Yellowstone River.

The telltale translucence of the stones is the one thing that helps to identify them. Taking into consideration that not all translucent stones are agates, close examination is sometimes necessary. However we may search a gravel bar, we are bound to miss gem-quality stones. It's an inevitable fact.

I had an enjoyable few hours at Crane and was off to my next stop at the community of Intake on state Route 16. One of my road maps didn't even have the courtesy to show the location, simply indicating a diversion dam on the Yellowstone River and a campground. Intake is 17 miles north of Glendive on state Route 16. Watch for the fishing access and campground sign as you approach Intake from either direction.

Strangely enough, I've passed this site on a number of occasions during my travels, but this was the first time I drove into it. I found a well-kept campground and a good boat-launching ramp on the shore of the Yellowstone River. I walked to the water's edge and looked upstream at the dam. It isn't what I expected. It appears to be a rock-filled berm about 6 feet high. The river is possibly 300 yards wide here during low-water periods. The current is swift.

I walked over to a concrete diversion dam not far from camp. It feeds water to a large irrigation canal. During my walk, I examined the ground around me for any signs of gemstone material. I saw nothing particularly interesting here. My main interest was the most inviting gravel bar that went for a great distance downstream on the campground side.

It was much cooler than the previous day had been and the sky was overcast when I began my search on the bar. Before long, even at my slow searching pace, I was out of sight of the campground. After a while, I stopped to admire the surroundings. From my vantage point, the gravel bar continued downstream from the campground all the way to the next bend in the river and beyond, approximately three-quarters of a mile.

I was anxious to find my first agate, so I concentrated on the cobblestones spread out before me. They were very clean, but it was difficult to spot an agate amongst the myriad river rocks on the bar. I persisted and concentrated on the search. It paid off.

As is the case at every site I've collected in, the farther one goes from the parking area, the more one's chances of finding quality stones increase. There's a penalty imposed, as well. We have to carry those stones a greater distance, and they do get heavy.

It wasn't long before I began to see an occasional translucent stone. Some were ordinary water-worn quartz nodules. Then I saw one with only a slight glint of yellow. It was covered with a thin layer of dirt, but it aroused my interest and I pried it loose from its mud-encrusted resting place with my pocketknife. I held a well-rounded, water-worn stone the size of a baking potato in my hand. I washed it off in the river, and it was immediately transformed from a drab, uninteresting rock into a beautiful, golden agate. It caused me to wonder how many gem-quality stones I had passed up during my years of collecting.

I was quite a distance from camp when I began to find the most interesting and beautiful pieces of agatized wood, as well as good quality moss agates, from marble size to 2 inches in diameter. They lay right on the surface, polished to a high sheen by nature.

I was thrilled to discover a large piece of agatized wood. The wood grain is so well duplicated that the piece appears to be a piece of contemporary driftwood instead of solid chalcedony. I could not pass it by. I had to have it. It's rectangular and measures 8 ¼ inches by 2¾ inches by 3¼ inches. It appears to have been some species of oak, the overall color is

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Yellowstone River agatized wood shows a high polish and evenly spaced, straight growth rings.

golden brown and the growth rings are chocolate brown, separated by very thin, oil white bands. It even has a large knot in it, which adds to its beauty. I also discovered a small thin streak of metallic luster near one edge. This will demand more careful sectioning. I once found a moss agate specimen with a tiny platinum needle in it, so who knows what this could be?

This once-living tree had good nourishment because the growth rings are spaced ⅛ inch to ¼ inch apart and there are, as near as I can count, 21 rings. The piece will have a special place in my rock collection.

It was time to return to the camper. I had this large piece of agatized wood, plus my pouch was getting heavy. On the way back, I forced myself to be extremely selective and I passed up innumerable good looking stones. Many of the stones that I collected can be made into fine jewelry.

The colors of the agates I found at Intake are phenomenal. I examined one stone the size of an apple and just as round. The colors in this one stone are yellow, brown, cream, off-white, blue, and even emerald green. When I washed it in the river, I thought at first that the green was algae clinging to the rock, but the green color is deeply imbedded in the agate. Cutting it should reveal even more beauty.

When I returned to the camper, a can of iced tea was a delicious, thirst-quenching treat. After a late lunch, it was still early enough to make one more short trip onto the bar. This time, I wasted little time and walked to the first bend in the river before diverting my attention to the ground.

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Treasure *from page 76*

The Crane gravel bar is two city blocks wide at one point

Collecting gemstones is much like eating popcorn. It's difficult to stop. I talked with one lady a while ago who had gone rockhounding for the first time. She told me that her husband was worried about her because it was getting dark and she hadn't returned. She was so engrossed in her search, she told me with a chuckle, that she forgot about the evening meal. Rockhounding is contagious, and once hooked, we never stop. It is akin to gold fever in many respects.

I've learned that the best time to collect better agates on the Yellowstone River is right after spring runoff. The next best time is the low-water period during late summer. During the spring, you're more apt to find stones that have been recently deposited. My choice has always been late summer. There are copious amounts of stones waiting for us at any time during the season along the Yellowstone River in Custer Country.

Go prepared. Wear a good pair of shoes, some grubbies, sunglasses with ultraviolet protection, and a hat or cap, and bring plenty of liquid, preferably water. Dehydration sets in often without warning. One of the symptoms is that we do not feel thirsty, so drink sufficient water while collecting on the bars. If you have a self-contained RV, the campground at Intake would be a pleasant place to stay while rockhounding. It's convenient and close to the action.

If you happen to be in the neighborhood of Intake, Montana, it would be well worth your while to visit this fantastic place in the Treasure State. Use caution while taking part in this wonderful outdoor activity and above all, enjoy the wonderful bounty that Montana has to offer.

Ghost Ranch DINOSAURS

New Mexico's Colorful Cliffs and Mesas Hide Fossils

Story and Photos by Steve Voynick

The fossilized bones of many phytosaurs, like this 10-foot-long specimen, have come from the Ghost Ranch quarries.

New Mexico's Ghost Ranch is known for colorful cliffs and mesas that were captured on canvas by its most famous resident acclaimed artist, Georgia O'Keeffe. Today, Ghost Ranch, located in northern New Mexico on U.S. Highway 84 some 60 miles northwest of Santa Fe, is a conference center owned and operated by the Presbyterian Church U.S.A. Each year, it hosts thousands of visitors, who participate in spiritual retreats, enjoy artistic activities, take in the beauty of the red rock cliffs, and savor O'Keeffe's legacy. Still others come to Ghost Ranch to visit the nation's most unusual fossil museum, the Ruth Hall Museum of Paleontology.

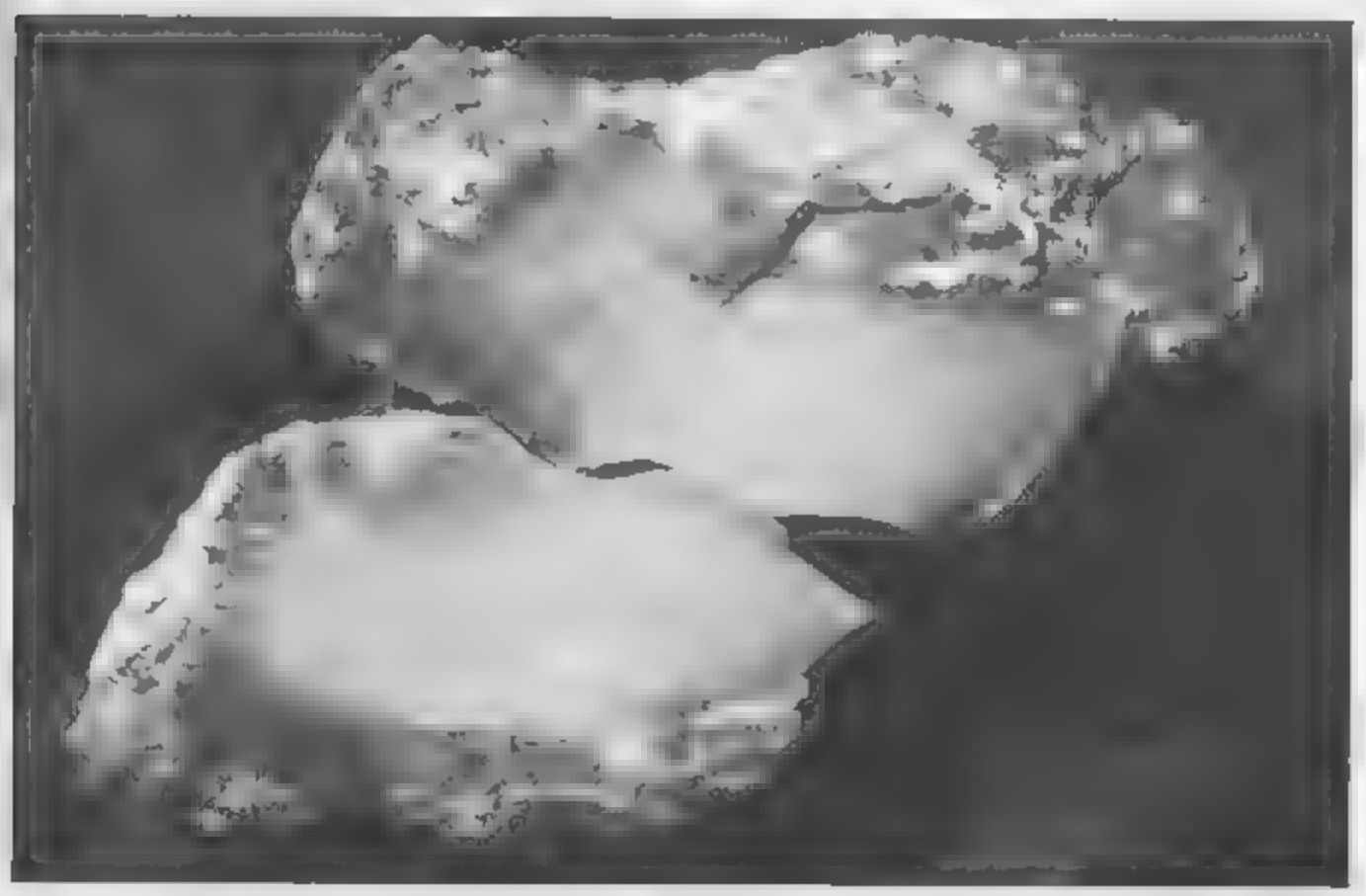
Ghost Ranch is the site of New Mexico's richest fossil deposit and one of the greatest vertebrate-fossil discoveries of all time. Its five fossil quarries have yielded hundreds of complete, articulated, and superbly preserved specimens of dinosaurs, crocodilelike phytosaurs, reptiles, and amphibians. But the star of the Ghost Ranch fossil show is New Mexico's official state fossil, Coelophysis bauri, a small, carnivorous, bipedal dinosaur that roamed what is now the American Southwest some 215 million years ago. Despite its diminutive size, Coelophysis has unusual paleontological importance: As the earliest dinosaur ever found in North America, it provides vital clues to life during the dawn of the dinosaur age.

Ghost Ranch is hidden away in the beautiful Chama River Valley, surrounded by the red-and-yellow cliffs of the Piedra Lumbre ("Shining Stone") Mountains. The 33-square-mile ranch was originally part of a Spanish land grant that was awarded to colonist Pedro Martin Serrano in 1766. Because of many eerie tales of ghosts and spirits, the ranch was first known as Rancho de los Brujos (Ranch of the Witches), the origin of its current name. By the 1920s, Ghost Ranch was no longer a working cattle operation, but an upscale dude ranch owned by conservationist and philanthropist Arthur Pack.

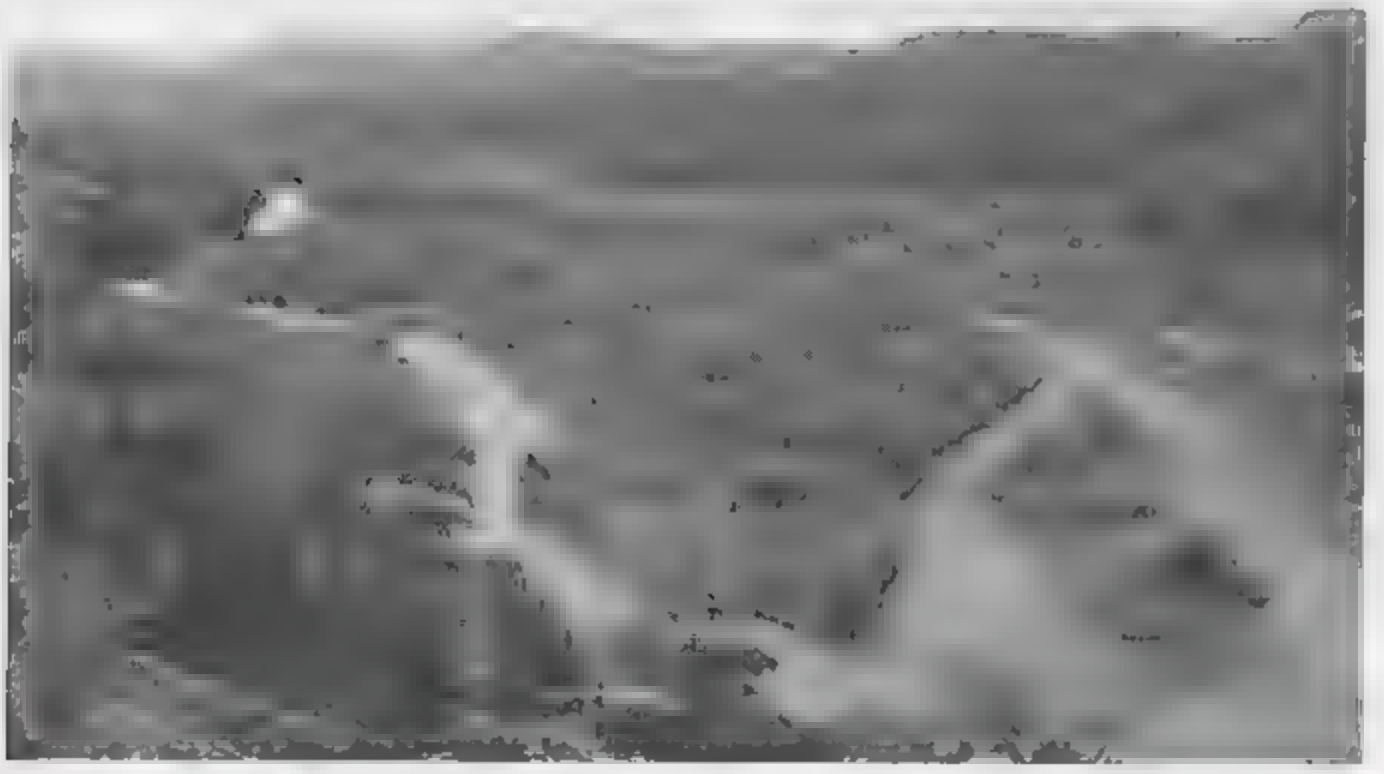
Ghost Ranch had long been known for unusual fossils. In the early 1800s, the discovery of a 3-foot-long, fossilized phytosaur skull with jagged teeth inspired the local legend of Vivaron, a huge, fearsome, child-eating reptile that lurked in the shadows of the cottonwood trees along the nearby Chama River.

In 1881, not far from Ghost Ranch, amateur fossil collector David Baldwin found fragmented bones of what seemed to be a small dinosaur. Baldwin sent the bones to paleontologist Edward D. Cope, who was then engaged in the so-called "Bone Wars," a race with his contemporary Othniel Charles Marsh to discover and name new dinosaur genera and species. In 1887, Cope assigned the fragmented fossils the genus name Coe-

This complete, articulated, fossilized Coelophysis skeleton, displayed at the Ruth Hall Museum of Paleontology, is one of more than 100 that have been recovered from Ghost Ranch.



Many Native American artifacts were fashioned from Pedernal chert from Cerro Pedernal, not far from Ghost Ranch.



In northern New Mexico's Chama River Valley, near Ghost Ranch, river erosion has exposed formations representing 80 million years in geological time.

tophysis (pronounced SEE-lo-fy-sis), meaning "hollow form" in reference to the hollow nature of the bones, which were themselves too incomplete to provide a clear understanding of the animal. Nevertheless, Cope and other early paleontologists agreed that the bones were unusually old and represented a very early stage of dinosaur development.

Intriguing reports of highly fossiliferous sediments attracted the first paleontologists, Charles Camp and Sam Wells of the University of California at Berkeley, to Ghost Ranch in 1928. They found numerous vertebrate fossils and opened the Canjilon Quarry, the first Ghost Ranch fossil quarry. Returning during the summers of 1930 and 1933, Camp and Wells recovered fossilized skeletons of reptiles, amphibians and phytosaurs. Another interesting find was a rare armored typothorax, a large herbivore, but it was the fossilized phytosaur skeletons, which included 11 skulls of both adults and juveniles, that put Ghost Ranch on the paleontological map as a site worthy of closer investigation.

Ghost Ranch's first national notoriety would come not from fossil discoveries, but from the arrival of Georgia O'Keeffe (1887-1986) in the 1930s. Enamored of the beauty of the ranch and its surroundings, the artist began spending summers there. In 1940, she bought a small house called Rancho de los Burros on a seven-acre section of Ghost Ranch. Here, O'Keeffe created some of her most emblematic images: voluptuous, oversized, brilliantly colored flowers, multihued cliffs, and grainy New Mexican skies, sometimes seen through sun-bleached animal skulls and antlers, and often with the flat-topped Pedernal, a regional mountain landmark, looming in the distance.

During World War II, Ghost Ranch served as a "rest-and-relaxation" center for overworked scientists who were developing the atomic bomb at nearby Los Alamos. After the war, such eminent nuclear physicists as Enrico Fermi, Robert Oppenheimer, and Richard Feynmann fondly recalled their stays at the ranch.

Paleontologists returned to Ghost Ranch in 1947. That spring, paleontologist George O. Whitaker of New York City's American Museum of Natural History, followed a trail of loose fossil fragments up a steep hill to an exposed fossiliferous ledge. Although Whitaker did not have the time or equipment to excavate, he did collect a few fragmented bones, which he showed to another American Museum paleontologist, Edwin H. Colbert. Colbert thought that the hundreds of small bone fragments might be those of the elusive Coelophysis, fossils of which had not been found anywhere for more than 60 years.

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Ghost Ranch Dinosaurs *from page 87*

That June while Colbert and his colleague George Gaylord Simpson were traveling to fossil sites in Arizona, they decided to stop first at Ghost Ranch. Following Whitaker's instructions, they quickly found the fossilized ledge, a stratum of the Painted Desert Member of the late-Triassic Chinle Group sandstones and shales. This ledge was just 2 feet thick, but after a bit of digging, Colbert and Simpson could see that it was loaded with fossils, almost all of them beautifully preserved Coelophysis bones.

After confirming the extent of the deposit, Colbert and Simpson cancelled their planned trip to Arizona. With the telegraph at the nearby town of Abiquiu inoperative, they traveled 30 miles to the Western Union office at Española on June 30th to send this wire to Carl Sorenson, director of the Paleontology Department of the American Museum: HAVE STRUCK RICH QUARRY NEED EXTRA HELP CAN YOU MAKE ARRANGEMENTS TO JOIN US AS SOON AS POSSIBLE IF POSSIBLE GET EXCURSION TICKET OTHERWISE ONE WAY SANTA FE OR ALBUQUERQUE CHARGE PALEONTOLOGY ENDOWMENT FUND WIRE COLBERT GHOSE [sic] RANCH ABIQUIU NEW MEXICO DATE AND TIME OF ARRIVAL WILL MEET YOU SIMPSON COLBERT.]

What Whitaker had found, and what Colbert and Simpson had confirmed, was a remarkable deposit that would provide paleontologists with badly needed insight into the earliest days of the dinosaurs. When help and equipment arrived a week later, Colbert and Simpson began supervising the initial phase of excavation. Within days they had uncovered dozens of complete, articulated, fossilized Coelophysis skeletons that would give the scientific community its first real look at this early dinosaur.

Coelophysis was built like a large, slender bird, with a streamlined body, S-shaped neck, and long, powerful hind legs. Its birdlike, lightweight skull had an elongated snout. Most adults measured about 8 feet from the nose to the tip of the extended tail, with the biggest specimens measuring 10 feet. Just 3 feet tall at the hip, an adult weighed only about 50 pounds. The streamlined torso conformed to the basic theropod body shape, the head and abdomen together were only 3 or 4 feet long, and the long, slender tail accounted for half the total body length.

Coelophysis was built for speed and agility. An unusual interlocking vertebrae structure provided both flexibility and rigidity, enabling the tail to act as a rudderlike counterweight when the animal was running.

The bladelike, recurved, serrated Coelophysis teeth, typical of those of predatory dinosaurs, were rooted deeply in the jaws and were continually replaced throughout the animal's life. Coelophysis was opportunistic in its feeding, both scavenging and catching live prey such as small reptiles, insects, and other dinosaurs. The presence of the bones of juvenile Coelophysis in the abdominal cavities of adult specimens gave rise to the theory that the genus was cannibalistic.

This exhibit shows the excavation and preparation tools used by Ruth Hall in her paleontological work at Ghost Ranch.

During the next five summers, field teams working in what became known as the Whitaker Quarry uncovered hundreds of Coelophysis specimens, about a quarter of which were complete and articulated, a degree of preservation almost unheard of in vertebrate paleontological excavations. Thanks to the large number of complete specimens in plaster "jackets" being shipped from Ghost Ranch to museums around the world, the once-rare Coelophysis soon became one of the of the most widely displayed of all dinosaur genera.

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Ghost Ranch *from page 88*

How such a large number of Coelophysis died together and why their remains were so well preserved was puzzling. Since knowledge of Coelophysis behavior was essentially limited to what had been extrapolated from the Ghost Ranch fossils, paleontologists first theorized that Coelophysis had moved about in large herds, a trait not at all typical of carnivore or theropod behavior. Another theory, that a large food attraction, perhaps numbers of carcasses, had drawn many Coelophysis together was not supported by fossil evidence.

The current prevailing theory is that large numbers of Coelophysis were drawn to a water hole during a drought. A flash flood then swept away many animals, whose remains were quickly and simultaneously buried in a subsequent mudslide. This theory has gained credence through the study of other fossil deposits that indicate flooding was common during the late Triassic Period.

Although normally reclusive, the artist O'Keeffe, who was intrigued by sun-bleached bones and often included them in her paintings, sometimes visited the Whitaker Quarry while excavations were in progress. Ghost Ranch owner Pack recalled how much she enjoyed her personal tours given to her by prominent paleontologists.

In 1955, O'Keeffe's solitude seemed in jeopardy when Pack unexpectedly donated the entire Ghost Ranch to the Presbyterian Church USA. The artist, who had wanted to buy the entire ranch herself, was aghast. Besides having no particular use for Presbyterians, the artist saw her precious privacy disappearing.

But Jim Hall, director of the new Ghost Ranch, respected the privacy of his famous neighbor and did his utmost to accommodate her, even allowing his staff to assist her with secretarial and maintenance work whenever needed. While Hall worked hard to eventually win O'Keeffe's acceptance, his wife Ruth, was also keeping busy. With ready access to both leading scientists and the ranch's extraordinarily productive fossil excavations, Ruth Hall immersed herself in paleontology. She quickly became an accomplished amateur paleontologist, assisting at major Ghost Ranch excavations, discovering and excavating her own sites, and building an extensive fossil collection worthy of public display.

Ruth also worked to gain state recognition of Coelophysis, efforts that paid off on March 17, 1981, when the state legislature adopted Coelophysis as New Mexico's official state fossil.

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Ghost Ranch Dinosaurs *from page 98*

O'Keeffe who, in her own words, found most people "very difficult," never forgot the Presbyterian Church's hospitality at Ghost Ranch nor Ruth's enthusiastic pursuit of paleontology. When fire destroyed the Ghost Ranch headquarters building in 1983, the 94-year-old O'Keeffe, in failing health and living in Santa Fe, made a substantial cash contribution to help rebuild the headquarters and to construct a paleontological center that would be named the Ruth Hall Museum of Paleontology.

Shortly thereafter, in 1990, Coelophysis became the locus of yet another scientific debate, this time over the validity of its name. Some paleontologists argued that the original incomplete and fragmented Coelophysis specimens collected in 1881 were not diagnostic in themselves, and therefore the name could not be applied to additional specimens specifically to the Ghost Ranch fossils. Instead they proposed the name Rioarribasaurus, after Rio Arriba County, in which Ghost Ranch is located. The proposed name change, however, would have caused problems for researchers, since Ghost Ranch Coelophysis specimens were now distributed worldwide and all paleontological literature used that name.

In the end, the International Commission on Zoological Nomenclature (ICZN) intervened. The ICZN, the paleontological and zoological counterpart to the International Mineralogical Association, which approves names for mineral species, decreed that the name Coelophysis would stand. To further clarify the issue, the ICZN transferred the designation of "Coelophysis type specimen" – the actual fossils used to define new genera and species – from the fragmented original specimens of 1881, to one of the well-preserved, complete Ghost Ranch specimens.

Until the late 1990s, Ghost Ranch had only two fossil quarries: the Cranium Quarry that had been opened in 1928, and the Whitaker Quarry of 1947. In 1996, paleontologists found phytosaur fossils at the Orphan Mesa section of Ghost Ranch. Two years later, they opened the Snyder Quarry, which yielded a diverse array of fossils of land vertebrates and water invertebrates. Then they opened the Hayden Quarry in 2002, an excavation that is still providing fossils of phytosaurs and small dinosaurs today.

New important paleontological discoveries continue to be made, even in rock that was excavated from the Whitaker Quarry 60 years ago. In 2006, paleontologists at the American Museum of Natural History opened an old plaster jacket to search for additional Coelophysis specimens. Instead of holding Coelophysis fossils, the jacketed block of rock contained the bones of a new archosaur, a small, two-legged crocodile ancestor that walked upright and had a beak rather than teeth. They named the new archosaur species *Effigia okeeffeae* in honor of Georgia O'Keeffe.

Today, the Ruth Hall Museum of Paleontology is well worth a visit for anyone interested in fossils. Its central exhibit is an 8-foot by 6-foot fossil-rich rock, the last block that was removed from the Whitaker Quarry in 1986. The block is displayed in partial relief, and if the timing is right, visitors can watch paleontological technicians working with chisels, hammers and picks to expose more delicate fossilized bones.

Among the dozens of museum exhibits is a fossil skull of "Pamelamosuchus," a new reptile genus recently discovered at Ghost Ranch. The 2-foot-long Pamelamosuchus lived in freshwater streams during the Late Triassic. Upon ICZN approval as a new genus, perhaps in a year or two, the quotation marks will be dropped and the formal taxonomic name will appear in italics in all future literature.

The museum also displays a complete, articulated Coelophysis skeleton in full relief, along with a 4-inch fossil skull of a juvenile Coelophysis, perhaps the smallest nonembryonic dinosaur skull exhibited anywhere. Alongside is a painting by paleontological illustrator Doug Henderson depicting two Coelophysis adults wading in a stream, an interpretation of what the Triassic environment of Ghost Ranch may have looked like 215 million years ago.

Another eye-catching exhibit is a cast skeletal mount of *Necrosaurus*, a 10-foot-long crocodilelike phytosaur, its jaws studded with jagged teeth.

About 95 percent of the fossils recovered at Ghost Ranch are those of Coelophysis. The second most abundant remains found in its late Triassic sediments are those of Hesperosuchus, a small, partially armored crocodilian that lived on land and had long, thin legs and a high, narrow skull. In the Ruth Hall Museum of Paleontology, Hesperosuchus is represented by both a complete fossil skeleton and a life-sized reconstruction.

Yet another display honors museum namesake Ruth Hall. It includes photographs and the paleontological tools she used in her work. She is a leading amateur paleontologist.

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Ghost Ranch *from page 92*

Adjacent to the Roth Hall Museum of Paleontology is the Florence Hawley Ellis Museum of Anthropology, where exhibits range from 10,000-year-old Paleo-Indian artifacts and ancient pottery to modern-day Southwestern crafts. Displays include many flaked stone tools and projectile points from regional Native American cultures.

Interestingly, many of these stone artifacts are fashioned from Pedernal chert obtained from Cerro Pedernal, the flat-topped, 9,862-foot-high mountain that looms to the southeast of Ghost Ranch. O'Keeffe called the mystical Pedernal "my mountain" and often made it part of her art. The tough, fine-grained Pedernal chert, which flakes easily, was an important trading commodity among regional Native American cultures. In the regional Spanish of northern New Mexico, the word *pedernal* means "flintstone knife."

Pedernal chert weathers from the massive formation of volcanic rock that caps Cerro Pedernal. It is mostly black or white in color and takes a fine polish. Large pieces weighing several pounds are easy to collect and are often fashioned into bookends and other ornamental objects. One collecting area is located near the town of Youngsville. From Ghost Ranch, follow U.S. Highway 84 six miles south, then take state Highway 96 10 miles to Youngsville, where Forest Service Road 100 tracks to the east alongside drainages filled with Pedernal chert.

In addition to its two on-site museums, Ghost Ranch has nine marked hiking trails, some leading to the fossil quarries. One trail ends at the Ghost Ranch Piedra Lumbre Education and Visitor Center, five miles to the north, which is also directly accessible from U.S. Highway 84. The center contains indoor and outdoor exhibits on area geology, paleontology and history. Spotting scopes help visitors identify the colorful geological strata on the surrounding cliffs that represent 80 million years of geological time.

Another nearby site of geological interest is located just four miles north of Ghost Ranch on U.S. Highway 84. The Echo Amphitheater is a 400-foot-high sheer cliff, mostly of red, early Jurassic Entrada sandstone, that has been wind-eroded to a smooth concavity and decorated with beautiful patterns of desert varnish.

The Roth Hall Museum of Paleontology and the Florence Hawley Ellis Museum of Anthropology at Ghost Ranch are open to the public year-round. For hours and additional information, write to the Ghost Ranch Conference Center, HC 77, Box 11, Abiquiu, NM 87510, call (505) 685-4333, or visit the Web site www.ghostranch.org.

Rock Science

by Steve Voynick

Monazite, Thorium and Lantern Mantles

Monazite is more popular among mineral collectors for its radioactivity, interesting history, and unusual chemistry than it is for its visual appeal. Monazite forms reddish-brown, equidimensional or slightly elongated monoclinic crystals that, while often well-developed, rarely exceed a half-inch in size. It has a conchoidal fracture, a Mohs hardness of 5.0 to 5.5, and a relatively high specific gravity of 5.2.

Monazite's name derives from the Greek *monazein*, meaning "to be alone," a phrase that aptly describes the mineral's occurrence as isolated crystals in igneous rocks, phosphate pegmatites, and certain carbonatites (carbonate igneous rocks).

"Monazite" is actually a group name for seven related minerals, including monazite-(Ce), monazite-(La), monazite-(Nd), and monazite-(Sm). These are phosphate minerals that are respectively rich in the rare-earth metal cerium and the lanthanide metals lanthanum, neodymium and samarium.

But monazite's greater claim to fame is that it can contain as much as 15 percent thorium, the most abundant of the four naturally occurring radioactive elements (thorium, actinium, protactinium and uranium).

A dark-gray, heavy radioactive metal with a high melting point, thorium once had no uses. Then in the 1880s researchers found that thorium compounds glow brilliantly when heated to incandescence, a thermal state at which certain elements and compounds convert high levels of heat energy to electromagnetic energy in the form of visible light.

In 1891, scientists developed the thorium gas mantle, a small asbestos-cloth bag that, when heated in a gaslight flame, emitted brilliant white light. Because thorium mantles made gaslights competitive – at least temporarily – with newly introduced electric lighting, the gaslight industry began manufacturing and installing thorium gas mantles by the millions. The result was a rush to mine monazite.

Although igneous rocks contain only traces of monazite, the weathering of massive formations frees large quantities of monazite crystals. Durable and moderately hard, monazite crystals do not completely wear away, but become rounded grains. Their density enables them to concentrate as "monazite sands" in placer-type deposits in rivers and along ocean beaches. Rich concentrations formed notably in places like India and Malaysia, where dredging monazite sands for their thorium content quickly became an important industry.

By the time scientists discovered natural radioactivity in 1896, the manufacture of thorium gas mantles – which are highly radioactive – was booming. Although gaslights would eventually be replaced by electric lights, many would continue in use for decades, and to keep them glowing brightly, thorium gas mantles were mass-manufactured in many nations until the 1940s.

Finally, in the 1960s, the environmental consequences of manufacturing thorium products became apparent. In the United States, many older thorium gas-mantle plants and plant sites were so heavily polluted with radioactive thorium wastes that the federal Environmental Protection Agency designated more than a dozen as Superfund cleanup sites. To avoid costly, mandatory compliance with a host of new regulations controlling the handling, shipping, storage and disposal of thorium products, manufacturers began seeking substitutes for thorium.

Nevertheless, the use of thorium gas mantles, mainly in campground lanterns, continued until the early 1990s. Although thorium's radiation is limited primarily to low-penetration alpha particles, improper disposal or storage of thorium mantles, inhalation of thorium dust or mantle ash, or thorium contamination of foods can cause serious health problems. By 1993, gas-mantle manufacturers had finally replaced thorium with the lanthanide metal ytterbium, producing mantles that, while somewhat less bright, are far safer to manufacture and handle.

Accordingly, thorium use and demand is now at its lowest level in more than a century. Monazite is now mined only for its rare earth and lanthanide elements, leaving an oversupply of byproduct thorium. Scientists are currently studying the radioactive metal as a nonproliferative alternative to uranium in the generation of nuclear power. Should these studies prove fruitful, monazite mining could again become big business.

The West Country Mines

A British Mining Region Makes the World Heritage List

Story by Kiera Tara O'Brien

Struggling economy aside, Cornwall and West Devon have finally made it to the big time. In July 2006, the extensive mining landscape of these two regions was awarded a place on the World Heritage list alongside other "global treasures" like the Taj Mahal and the Great Wall of China. The deep mines of Great Britain's West Country now officially belong to the world, a preserve of cultural and natural heritage that is of exceptional value to humanity.

Hardrock mining is in the blood of the West Country, sometimes called the "cradle of Britain's Industrial Revolution." The craft is 2,000 years old, but the boom (and the bust) of the last two centuries have locked this landscape on the global cultural map.

The West Country is Britain's most important region for nonferrous metals, its one-and-only for tin, and a major supplier of copper and arsenic. Located on the southernmost tip of Britain and completely exposed to the Atlantic, Cornwall and West Devon have a rough landscape with an unpredictable climate, stark cliff faces, and treeless moors. The constant force of the Atlantic has eroded away the softer rocks of the area, leaving a heavy surface of tough, resistant granite. The famous Cornish cliffs, high moors, and strange igneous outcrops like Bodmin Moor and Land's End are all hardrock hall-of-famers. In the interior and northeast of the region, geologists have identified largely Devonian sandstone and Carboniferous sandstone and slate. The oldest section of Cornwall, the Lizard Peninsula, contains metamorphic rocks dating to the Precambrian era of around 640 million years ago.

The granite geology of the West Country destined it to become a major mining locale. As the granite masses in the area cooled in prehistoric times, large fissures cracked open, allowing molten rocks carrying minerals to slosh toward the surface. The minerals in the molten rock crystallized into lodes of tin, copper, lead, iron and zinc in long, vertical chains. Each fissure needed its own mine shaft stretching deep into the Earth; Cornwall was the new Holey Land of mining.

During the 18th century, West Country miners were pioneers in the process of deep copper mining. Innovative engineering techniques and logistics were required to penetrate the fruitful copper and tin lodes buried far underground in tough rocks. Cornwall was undoubtedly the most significant hardrock mining region in the world by the early 19th century, while neighboring Devon, with its tin and copper sources in Dartmoor, was a close rival.

BOB JONES PHOTO/RASHLEIGH COLLECTION, ROYAL CORNWALL MUSEUM

Perhaps the world's most striking specimen of liroconite, this 2-inch-long piece was unearthed in 1811 from the Levant Mine.

BOB JONES PHOTO/PRIVATE COLLECTION

Small, reddish chalcotrichite crystals come from the Fowey Consols Mine at Tywardreath, Cornwall.

As in Cornwall, ores had been mined in Devon since before the Roman invasion of Britain under the Emperor Claudius and expanded to commercial size in the 1700s. Many scholars argue that the Great Consols Mine of Devon was actually the largest copper mine in the world in the 18th century, even surpassing the size of the Cornish efforts for a period of time.

Whether Cornwall or Devon achieved supremacy in the scale of their mines, it is clear that mining in this region was a serious challenge. The depth of the mine shafts presented major roadblocks to workers in terms of water drainage, transport of the ores, supporting architecture, and engineering. Cornish industry thrived as local foundries collaborated with Britain's top engineers to improve the design of steam engines, pumps, winders, and a host of other technologies of the time. This was beneficial not only to the local industry and economy of the West Country, but to mining and engineering enterprises all over the British Empire during the Industrial Revolution.

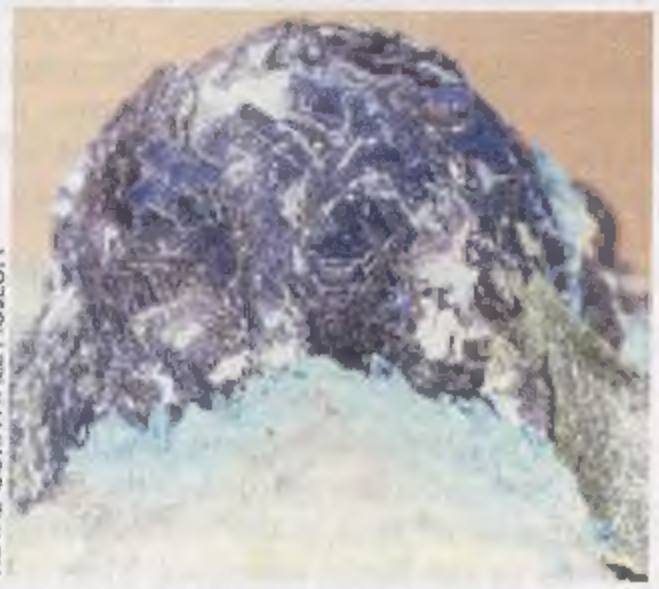
As the vertical mine shafts stretched well below the water table, substantial pumping networks were required to keep the miners moving down. High-pressure steam engines, developed by local Cornishman Richard Trevithick, were employed to drain the water from the deepest shafts and later powered the world's first motorized road vehicle. At the zenith of production, there were around 600 steam engines working across the many open mine shafts in the landscape.

The revolution wasn't restricted to engineering efforts, though. The famous Cornish pasty made its debut in this period. Easy to carry around, this hearty repast with savory filling in one end and sweet in the other was the ideal daily meal for hungry miners.

Economically and socially, the West Country was transformed from a remote seaside society into a buzzing center of economic investment, populationgrowth, and mining culture. The Cornish people identified personally with specific mining areas where they worked and became increasingly dependent on the mining industries. New settlements were established with rows of housing for the working-class communities, while the ever increasingly wealthy middle class benefited from the influx in capital to the region and built grand estates that proved serious competition to the more established, ultra-wealthy upper class gentry.

BOB JONES PHOTO/RASHLEIGH COLLECTION, ROYAL CORNWALL MUSEUM

Deeply colored olivenite crystals can occur alone, or with other species, such as liroconite.



BOB JONES PHOTO/RASHLEIGH COLLECTION, ROYAL CORNWALL MUSEUM

Philip Rashleigh's historic collection includes fine Cornish clinoclase.

At the height of its phenomenal production in the 19th century, the West Country had more than 2,000 active mines and was the greatest commercial enterprise in Europe in terms of scale, value and output. The 340 mines in the region supplied over a third of the world's copper and tin and employed more than 50,000 men, women and children.

Millions of tons of rock and tin were dug out by men underground and processed by women working on the surface for exportation around the world. After it was removed from the shafts, the rock was pulverized with stamping machines to separate the ores from the granite and slate. This was followed by more careful removal of impurities like arsenic.

The major mining areas of Cornwall were located at Penwith, St. Just, Camborne, Illogan, St. Agnes, Wendron, Gwennap, the Carnon Valley, Callington, and Wadebridge. The St. Just mines are among the most famous sites in the region due to the excellent preservation of the mining landscape, the town, and the mine machinery. Commercial mining started in 1820 and lasted until 1930, with the final mine, Geevor at Pendeen, closing in 1990. In this landscape of slate, greenstone and granite, the miners worked long copper and tin veins that could stretch out a mile under the sea. The National Trust and the Cornwall County Council have ensured that this remote area has been well looked after.

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West Country *from page 105*

Cramped and boiling hot with little fresh air to spare, even for the flame on the miners' candles, the Cornish mines were unforgiving places to work. There were no cages or elevators, so the miners accessed every inch of their shafts by ladder. Some miners recall emptying pools of sweat from their boots in heat that could reach almost 60 degrees Celsius (140 degrees F).

Starting work at the tender age of 12 and lasting until about 40, the Cornish mining boys became men very quickly. The film "The Mathematics of the Mole" (1962) and the BBC documentary "The Tin Miner They Couldn't Kill" (1972) capture the lives of the miners and the conditions in the tin mines, recalling the emotion and danger of life underground in the early 20th century.

In the deep recesses of the Earth, where rockfall, explosion, heat exhaustion, bronchitis, or tuberculosis could cause severe injury or take a life on any day, the miners developed a tight-knit community, often singing in chorus in the dark tunnels. On the surface, children under 12 and the women, or "Bal Maidens" as they came to be known, processed the rocks coming from below or loaded arsenic onto wagons. When the mining industries eventually collapsed, the Bal Maidens and their mining families abandoned the region in one of the largest exoduses of the time, fleeing mainly to Australia and America.

Tin and copper weren't the only precious specimens coming out of the deep West Country mines. Where there are ores, there are minerals. Smaller deposits of zinc, cobalt, nickel, uranium, iron, manganese and bismuth were uncovered, along with a rich variety of minerals. The most famous of these are the rare specimens of liroconite.

First found in the late 18th century in the Gwennap district of Cornwall, largely from the Wheal Gorland mine, liroconite forms as a secondary mineral in conjunction with copper deposits. At its home locality, liroconite crystals reach up to 3.5 centimeters in pyramidal shapes. These specimens range from a light, sky blue to a deep, vibrant blue or even a greenish color and are a characteristically Cornish mineral.

Renowned mineral collector Phillip Rashleigh owned several liroconite pieces and discusses them in his publication "Specimens of British Minerals." One of the beautiful specimens Rashleigh describes, generally regarded as the finest example of its kind in the world, can be viewed in the Royal Cornwall Museum in Truro, Great Britain: "Transparent

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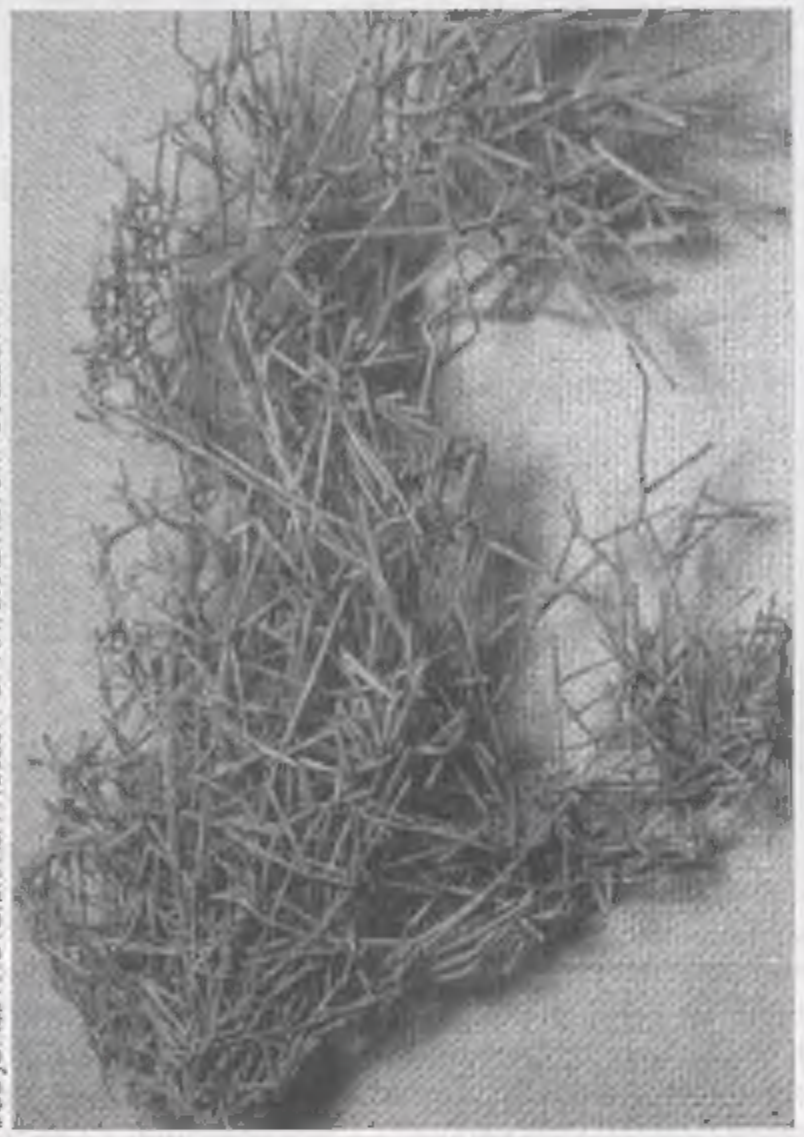
Crystals of Copper Ore in double four sided Pyramids of a bright blue colour the largest crystal 9/10 of an Inch on one edge from Wheal Gorland r.r.r. [very rare]" "Specimens of British Minerals," Vol. 1-2, W. Bulmer, 1797-1802).

Wheal Gorland is well known for producing not only high-quality copper arsenate specimens of liroconite, but also specimens of connellite, olivenite, langite, cuprite, cornwallite and chalocopyllite. A number of authors have recorded their experiences at this mine and the character of the minerals found within. W. Frances writes in the *History of Gwennap* (1845), "We pass through Wheal Gorland once without peer, for colours the rarest of very rich ore, and beautiful minerals valued yet more" (www.gorland.com). A thorough insight into Wheal Gorland, however, is best represented by the writings of William Phillips in the "Transactions of the Geological Society of London in 1811," an interesting read for anyone curious about Cornish mining.

Other minerals common to Cornwall and Devon include the dark-reddish cuprite (and a more fibrous form of this called chalcotrichite), which is also a product of copper sulfides, and the white to grayish dolomite found in small crystal clusters. Another secondary arsenate found in association with copper deposits is clinoclase, a rare mineral produced in display-quality specimens from Wheal Gorland and Wheal Unity in the Gwennap district. Cornish miners used to speak of discovering "beetle ore," balls of rich blue to black crystal clusters of clinoclase that were generally about 2 centimeters in diameter.

The famous St. Just Mine is known for a few other specimens, as well, including dense and tiny cassiterite crystals (a very Cornish species) and stunning calcite pieces in various fun formations, but always a cloudy white color. Wheal Jane was the type locality for brilliant examples of ludlamite, while the Geevor Mine produced a faithful supply of blue chalcocite right up until its closure.

In addition to permanent displays on the history and natural history of Cornwall, the Royal Cornwall Museum in Truro (tel: 01 872 272 205) counts an enormous mineral collection of over 10,000 specimens amongst its most intriguing and important possessions. A large portion of this collection came from the rather impressive personal collection of Phillip Rashleigh (1729-1811) of Menabilly.



BOB JONES PHOTO/BRITISH MUSEUM OF NATURAL HISTORY COLLECTION

Wires of native copper lightly coated with malachite are known from the Carn Brea Mine.

Rashleigh's collection—one of the largest in Cornwall with many examples of local mineral species, including brilliant examples of clinoclase and liroconite—is one of the only 18th century mineral collections to remain largely intact. It includes a single blue monoclithic liroconite crystal on a matrix of smaller crystals that is considered the premier example of this mineral species. It was discovered in 1808 in a rich oxide zone at Wheal Gorland. A nearly spherical clinoclase crystal measuring 2.5 cm across also comes from Wheal Gorland.

Rashleigh's home, Menabilly, was made famous as the setting of Daphne Du Maurier's classic novel *Rebecca*, in which it was renamed Manderlay. This was not the only literary mention Rashleigh's life received. Angered by Rashleigh's refusal to allow him to view his famous mineral collection, Sir Walter Scott decided to embarrass the stubborn collector in the pages of his novel about a Scottish rebel called Rob Roy. The villain of his classic novel was a nasty, treacherous character known as Rashleigh Osbaldistone, a name cleverly designed to exact a lasting literary revenge on the mineral enthusiast.

A hotbed of rare and beautiful mineral species and a monument to one of the most rapid periods of economic, social and technological experimentation and achievement, the Cornwall and West Devon mining landscape is undoubtedly the grandfather of our modern civilization. Now it's just official.

Foreign competition from new ore discoveries in Australia eventually depressed the price of copper and tin to the point that Cornish mining efforts became unprofitable. Although the outbreak of wars in the early 20th century briefly revived the industry, the mining operations of the West Country eventually collapsed, with the last mine, South Crofty, closing in 1998.

The area covered by the World Heritage protection includes all the mining sites at which physical remains have survived, most of which date to the late 18th- and 19th-century boom times. Ten areas have specifically been recognized as best representing the many faces of West Country mining culture: St. Just, Gwennap/St. Day, Hayle, Camborne/Redruth, Godolphin/Tregonning, Wendron, St. Agnes, the Luxulyan Valley, the Tamar Valley, and Tavistock.

The new World Heritage status is an important achievement in securing a long-term future for the mining landscape. At the St. Just Mine, an ongoing 10-year preservation project was one of the key factors in the bid for World Heritage status, which has saved more than 2,000 shafts and 13 engine houses. The South Crofty Mine has recently been opened to interested tourists. With mining hats on and torches in hand, a pair of former miners will take visitors on a trip through their old stomping grounds.

Other regeneration projects have ensured that a variety of ruins and remains in the area can be safely visited today. There are networks of tram and railways, the Copperhouse Foundry, and Harveys of Hayle, where steam engines were manufactured. The Great Country Adit, consisting of 38 miles of underground tunnels used to drain the mines, and a scattering of machinery and mine structures can also easily be reached with any local map or by asking one of the locals.

The decision to award the mines World Heritage status is hailed as a great landmark in the revival of the local economy, which relies heavily on tourism in the wake of the mining, fishing and farming industry downturns. Investment in the region is beginning to take an upward turn now, with many tourists flocking to the beautiful scenery and exploring the fascinating history of the mines and the tin and copper industries. The future is bright for this former grande dame of the mining world.